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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

PRINCIPLES OF PALEOGEOGRAPHY[1]

INTRODUCTION

THE science of the geography of past geologic periods, which is sometimes known as paleogeography, is a young science that has all its future before it. It springs from several older sciences: geography, geology, meteorology and paleontology; and in its development it must rest upon their general principles.

Paleogeography may be defined as the science of geography of all periods of the globe's history since earth, air, and water assumed those states in which they now exist. The science does not extend to any earlier state of the world. But from the time of the earliest lands, seas, and atmosphere to the present, the sequence of geographic conditions comprises the facts of paleography.

The science is very comprehensive. It includes not only the arrangement of continents and oceans and their individual features, but also the topography of lands, the circulation of oceanic waters and of the atmosphere, the climate, and the distribution of life, which were characteristic of the earth's surface during any particular epoch. It must trace the changes in these features from epoch to epoch, and with the aid of all allied physical and biological sciences, paleogeography should search out the ultimate causes which actuate the de-

[1] Address of the vice-president and chairman of Section E—Geology and Geography. American Association for the Advancement of Science, Boston, December 28, 1909.

velopment of the earth's superficial forms and of the earth's inhabitants.

The science of geography, as it is commonly understood, relates to a single geographic condition, that of the present. There have been many others in the past.

The present geographic condition or geography is peculiarly distinguished by large continents and high mountains, by extremes of polar cold; by great humidity of some regions and excessive aridity of others, and by corresponding diversities of faunas and floras. The geography of Quaternary time has been and is abnormally developed.

The geographies of the past have been individual also; sometimes, though rarely, they have exhibited extreme characters, equal in diversity of conditions to the Quaternary period; but as a rule extremes have been less pronounced and a nearer approach to simplicity of features has prevailed.

Could we at any past time have viewed the earth from without with an all-seeing eye, during any one epoch, we should have seen a single geography, a panorama. If we might have maintained our vigil from age to age during all her history as the globe, we would have observed the succession of geographies, a long procession.

In that procession we would have seen moving forward the great lines of evolution in the animate and inanimate world.

Slowly rising in response to the working of internal terrestrial forces, continents have emerged from the waters. Wasted by erosion they have in part been submerged again. Again they have risen and again sunk. The rhythm of their movement, the grand rhythm of the sphere, is timed to millions of years.

In comparison transient as the passing seasons of the year, mountain chains have grown under temporary though titanic stresses of the crust, and have wasted under the rays of the sun and drops of rain. Generation after generation of ranges has appeared, paused, and passed; incidents of the geographic procession, but integral features of it, obeying in time and place the law of its progress.

Atmosphere and ocean, those fluent envelopes of the sphere, have to outward appearance been least changeable, but they also have changed. Their currents circling westward against the revolving sphere and returning eastward, have adjusted their courses to the seas and lands. Subtly too the air and waters have been modified chemically as the critical constituents of the air and the soluble salts in the waters ran their changes in the laboratory of land and sea.

All of the changes suggested are linked in a chain of cause and effect, from continental movements to atmospheric circulation. Finally the evolution of living organisms is conditioned by them all. The life impulse, tending to develop new forms, has been helped or hindered by environment. Favored by congenial and widening habitats, faunas have diversified, become enriched, have spread, and attained cosmopolitan range. Or restricted to narrowing uncongenial districts, they have lost by extinction of the unadaptable elements and become limited to the surviving fittest. Had environment been unchanging, evolution would have run its course chiefly according to the intrinsic influence of the life-principle, but since environment has ever been changing, adaptation to modified external influences has played a dominant rôle.

The great procession of geographies, which has moved down the ages, has obeyed those laws of inorganic and organic change, which we recognize as the principles of

geography, geology, oceanography, climatology, paleontology and evolution. The principles of astronomy, physics, chemistry and biology are also involved to the extent that they enter into the development of geographic conditions.

Because paleogeography is thus comprehensive, no one investigator can adequately solve its problems. A group of students only can do the science justice. In attempting this statement of its general principles, I do not fail to recognize the fact that it must be incomplete and qualified by inadequate understanding of many of the branches of knowledge involved.

PERMANENCE OF OCEAN BASINS

Oceanography is a science which as yet scarcely ventures over the threshold of the present upon the long vista of the past, but the guidance of paleogeography leads that way. From the study of ancient lands and epicontinental seas we are led directly to the recognition of ancient ocean basins; it is, however, particularly among European geologists, still a mooted question whether the hollows, which the waters occupy, have constantly existed as hollows or may have been sites of continents which have now sunken in. The evidence that the hollows have constantly existed is strong. Upon it rests an assumption, which must be either affirmed or denied, there being no third condition, and which may be stated in the affirmative form as a principle:

The great ocean basins are permanent features of the earth's surface and they have existed, where they now are, with moderate changes of outline, since the waters first gathered.

This conclusion rests upon three principal facts:

The continents have never been submerged to oceanic depths and consequently can not have been replaced by deep hollows.

The oceanic basins have always been of such capacity that they contained by far the larger part of the waters, which have overflowed on the continents only as relatively shallow epicontinental seas; hence no considerable part of the existing basins can ever have been occupied by land.

There is a relation between the intensity of gravity and the relative altitude of a continental or oceanic plateau, which proves that the plateaus have assumed different altitudes according to the densities of the subjacent material. The transformation of a continent into an ocean basin, or *vice versa,* would require, therefore, a change in density of an enormous volume of material, and there is neither evidence nor explanation of such a change.

A few words may be said in support of these propositions, but before doing so a distinction should be made between the great ocean basins and those deep troughs which have from time to time developed within continental plateaus and which Dana called geosynclines.

In their genesis ocean basins and geosynclines may have been similar; but in their dimensions, histories and structural relations they are radically different.

I will not dwell on the great magnitude of the Atlantic or Pacific basins in comparison with the Appalachian or Cordilleran geosynclines. They need but be named.

The history of a geosyncline comprises a prolonged stage of subsidence accompanied by more or less constant deposit of terrigenous or marine sediment, and often a further stage of compression, folding of strata and elevation as a mountain range.

The history of ocean basins does not exhibit a similar stage of subsidence within the eras of the geologic record, although the hollows have sometimes apparently

deepened enough to affect the extent of epicontinental seas. And no ocean basin has been compressed, crumpled and raised, after the manner of the Appalachians or Alps.

The structural relations of geosynclines are intra-continental, those of oceans are extra-continental. The geosyncline occupies a position among the positive continental elements. The oceanic basins separate and surround continents.

The distinction between geosynclines and ocean basins is thus fundamental, and to reason from the history of the one to that of the other, as has sometimes been done, is necessarily misleading.

This distinction noted, we may return to the proposition that the ocean basins have always been permanent since ocean waters gathered.

The evidence is clear and unquestioned that marine waters have circulated and marine faunas have migrated from epicontinental seas of the eastern or western hemisphere to those of the other hemisphere, and they could only have done so across or around bodies of water occupying the sites of the present oceans.

We have good reason to assume that the volume of oceanic waters has not changed materially from what it was at the inception of existing conditions, it being apparently true that contributions from within the earth have been relatively small during geographic eras, and none being known from without.

The ocean basins are now somewhat overfull; they are not large enough to hold all the waters, which therefore extend over the margins of the continents. During certain epochs of the past the waters have spread farther, the basins having then been less capacious; again during certain other epochs the waters have withdrawn into deeper or wider basins. These variations have lain within narrow limits as compared with the total volume of the oceans, and they have occurred repeatedly, in alternation. Had a continent ever existed in place of one of the ocean basins, it must on sinking to oceanic depths have produced a disturbance of these nicely adjusted relations, of which the geologic record shows no trace; which must, however, have been of such magnitude that it would have marked off an older era of small lands from a later one of great continents. No such event has taken place, and no continent of oceanic extent has sunk to oceanic depths.

This conclusion bears on the reconstruction of former continental extensions. If we accept the evidence that Appalachia formerly extended southeastward into the Atlantic, we must consider reasonable limits. If we erect a transatlantic land to connect Africa and South America, or postulate a Gondwana land from Africa to Australia, we must provide for the waters which such lands displace. The ocean basins and possible epicontinental seas are the only refuge for the waters which are thus hypothetically evicted, and their capacity may be overtaxed.

The capacity of a basin being affected by changes in depth or width, it is obviously possible to argue that narrower but deeper basins may formerly have contained the waters that are now held in wider and possibly shallower ones. To a certain extent this view may be entertained, but it has limits and they are close to present conditions. The average depth of nearly two thirds of the ocean's basins below the continental plateaus is 4,000 meters or more. At this difference of altitude the weight of the continental column crushes its base and creep ensues. The depth can not be materially increased without occasioning corresponding spreading and low-

ering of the continental plateau, till the present condition of approximate isostatic balance were reached.

The postulate of isostatic equilibrium among masses of unlike densities in the earth's crust has recently been strongly supported by the work of Putnam[2] and Gilbert[3] on gravity in the United States, of Hayford[4] on the deflection of the plumb line in the United States and of Hecker[5] on the attraction of gravity on the oceans.

Hecker puts the general conclusion thus:

> It follows that not only the superficial masses of the continents must be compensated by a defect of mass, a less density in the earth's crust under the continents, but also that there is compensation beneath the deep seas through the greater density of the ocean bottom.
>
> Inasmuch as it has been shown that Pratt's [Dutton's] hypothesis of the isostatic relations of masses holds not only for the continents, but also for the three oceans (Atlantic, Pacific and Indian), we may regard it as a law which, apart from certain disturbances, is a general one for the earth's crust.

This conclusion appears to place the permanence of ocean basins outside the category of debatable questions.

A conclusion which follows closely from that of the permanence of oceans, is the *constancy of the major oceanic drifts or currents from an early date in each of the great oceans.*

Movements of ocean waters result from winds and differences of density of the waters. The trade-winds and their complements, the westerly winds of higher latitudes, are due to causes which have existed since the atmosphere and oceans formed; to rotation of the earth and to the distribution of the sun's heat. These causes operating through the winds on water bodies of oceanic dimensions must have always produced an east-to-west equatorial current, which being diverted by continents, developed great circulatory movements in the several ocean basins, flowing clockwise in the northern hemisphere and anti-clockwise in the southern. On the basis of the arguments just presented, the ocean basins are permanent, and hence the great superficial oceanic currents which characterize them must be regarded as equally ancient in their main features.

This conclusion regarding superficial currents does not necessarily apply to the deeper circulation, and there are reasons for believing that the latter is now abnormal. The deep-seated circulation is occasioned by differences of density or head, dependent upon temperature, salinity, precipitation and heaping of the waters by wind. Chamberlin[6] has suggested the analysis of these factors and has brought out the possibility of a change in the equilibrium of the waters, which may have resulted in *warm highly saline currents flowing poleward from the equator, beneath cool relatively less saline currents flowing toward the equator;* the reverse of the present condition.

The density of polar waters is attributed primarily to cold, and, as Chamberlin points out, may be increased in those regions where ice forms and where there are no large rivers by the salts forced out of

[2] Putnam, G. R., "Results of a Transcontinental Series of Gravity Measurements," *Phil. Soc. Wash. Bull.*, Vol. XIII., pp. 31–60, 1895.

[3] Gilbert, G. K., "Notes on Gravity Determinations by Mr. Putnam," *ibid.*, pp. 61–76, 1895.

[4] Hayford, J. R., "The Figure of the Earth and Isostasy," U. S. Coast and Geodetic Survey, 1909.

[5] Hecker, O., "Die Schweresbestimmung an der Erdoberflache und ihre Bedeutung für die Ermittelung der Massenverteilung in der Erdkruste," *Zeitschr. der Gesell. für Erdkunde*, Berlin, No. 6, 1909.

[6] Chamberlin, T. C., "On a Possible Reversal of Deep-sea Circulation and its Influence on Geologic Climates," *Jour. of Geology*, Chicago, Vol. 14, 1906, p. 363.

the superficial layers in freezing. Were the more profound causes of the climatic state so modified as to ameliorate the severity of polar cold, both of these influences would be moderated, and the effects of freshening by rivers and precipitation would not be offset to the extent that they now are.

On the other hand, equatorial waters are warmed and evaporated, and they are thus rendered light because warm, yet heavy because saline. The actual density, as compared with that of polar waters, is now less than the latter, but both observation in the oceans and calculation show that the balance is small. Were the polar waters less chilled or more freshened or both, the equatorial waters would be heavier, and the reversed circulation suggested by Chamberlin must result.

The cold of the present polar climates is extreme and unusual. To whatever fundamental causes we may attribute it, we know that it did not exist during the Miocene, Eocene, Cretaceous, later Jurassic, Carboniferous, Devonian, Silurian, Ordovician, or later Cambrian. Frigid conditions may have occurred with severity in the earlier Jurassic or Triassic and in the early Cambrian or late pre-Cambrian. That is to say at periods which, like the present, were periods of exceptional continental expansion and elevation. It seems to follow cogently that the condition of oceanic circulation which depends upon polar cold is also exceptional. Under more genial conditions, the waters in high latitudes would be lighter than now because warmer. They would also be more generally freshened by precipitation, and nowhere rendered more saline by freezing. The conditions which now occasion the greater density of polar waters would thus fail and the balance would sink on the side of the equatorial waters. Heavier equatorial, lighter polar waters have probably been the normal condition; the reverse, which now exists, the abnormal.

This conclusion follows entirely apart from the consideration that the extraordinarily mild climates of some ages are rendered less difficult to understand if the deep-seated circulation of the ocean were thus reversed, if it had normally been a movement of warm waters in the depths, instead of at the surface, toward the pole. But the facts, which it explains, strengthen the hypothesis and place it in the front rank of important suggestions in the study of paleogeography.

PERIODICITY OF DIASTROPHISM

Diastrophism, the process which comprises all movements of the earth's crust that modify continents or give rise to mountain ranges, has been characterized by periods of activity in alternation with periods of quiescence, throughout all geologic history.

This principle of the periodicity of earth movements rests upon the observation that periods when continents emerged from the sea and became mountainous have alternated with periods when continents had become low and were extensively submerged.

The emergence of continents and the growth of mountains are due to activity of the internal terrestrial forces; the reduction by erosion to low lands and the resubmergence mark the period of inactivity. The Quaternary is a time of decided activity, resulting in large continents and great mountain chains. It has been preceded by times of relative quiescence and by others of greater movement, in alternation, as far back in the past as the record goes.

While geologists in general will agree that this is a true principle, they find it

more difficult to define the respective periods.

It is possible to recognize at least three grand cycles from late pre-Cambrian time to the close of the Mesozoic, each grand cycle consisting of a long period of activity and a still longer time of relative quiet, thus:

Late pre-Cambrian activity (apparently somewhat general), Cambrian and Ordovician inactivity (general),	nth cycle.
Silurian and Devonian activity (qualified by circumpolar quiet in the north), Late Devonian and early Carboniferous inactivity (general),	$(n+1)$ cycle.
Later Carboniferous and early Mesozoic activity (non-contemporaneous in different dynamic provinces), Later Mesozoic and early Tertiary inactivity (general),	$(n+2)$ cycle.

Later Tertiary and Quaternary then constitute the initial, active period of the $(n+3)$ cycle.

While these grand cycles may be recognized for the whole world as far as we know the facts, it is found that each one may be divided into epicycles consisting of shorter periods of emergence and submergence *especially if attention be fixed upon a single ocean basin and the continents adjacent to it.* The North Atlantic, for instance, is bounded on the east and west by lands, which have been disturbed or have been at rest during the same epochs, and the several cycles have been of much shorter duration than those enumerated above for the whole world. These cycles are indeed those on which the time-scale of geologic history is based, and each one corresponds in general with a standard period, Carboniferous, for example.

Lands about the Arctic Ocean did not share in the Atlantic movements of Silurian, Devonian or late Paleozoic epochs. On the contrary, the great epicontinental seas of those periods were circumpolar. Nor do lands about the North Pacific, from California to China, record a history parallel with that of eastern North America and northwestern Europe, with the Atlantic history. In the Atlantic provinces, the Paleozoic era closed with marked diastrophism, while comparative tranquillity reigned around the Pacific; but the Pacific provinces were greatly disturbed in the middle Mesozoic when quiet had supervened about the Atlantic. Again, a distinct series of movements is recorded in the great geosyncline of Eurasia, that which stretches from India to Spain and is now marked by the system of mountain chains of which the Himalaya and the Pyrenees are the extremities. Similar movements appear to characterize the West Indies and northern South America. If, as I believe, these parallel movements in Eurasia, South America and the Indies originated in a common dynamic region, then that region is the great ocean of the southern hemisphere, including the South Atlantic, the South Pacific and the Indian oceans.

The principle of periodicity is necessarily qualified by these facts and the general law should be supplemented by one which recognizes unlike dynamic histories of different oceanic regions. It may be stated thus:

The phenomena of diastrophism are grouped according to several distinct dynamic regions. Each region has experienced an individual history of diastrophism, in which the law of periodicity is expressed in cycles of movement and quiescence peculiar to the region. The cycles of one region have been, however, to some extent parallel, though not conterminous, with the cycles of other regions, and thus major cycles of world-wide condi-

tions are constituted by coincidence of regional conditions.

The periodicity of diastrophism is the fundamental fact of geographic history. It carries with it corresponding periodic effects, both direct and indirect, in erosion, sedimentation, climatic changes, and even in organic evolution. All of these processes depend upon the initiative action of the earth's internal energy and they all are rhythmic because its action is rhythmic. Thus this general principle gives rise to correlative principles, which may be stated independently for each of the processes.

PERIODICITY OF EROSION AND SEDIMENTATION

American geologists need no restatement of the phenomena of cycles of deposition and erosion which Newberry[7] emphasized and which have led through the work of Powell, Gilbert and Davis to recognition of the principle that epochs of marked relief and vigorous erosion have alternated with periods of base-leveling, and that sediments have alternated correspondingly in character and volume. I may pass the subject of base-level periods and orogenic epochs as related to erosion and sedimentation with this reference to it, mentioning only that it is the essential principle in Chamberlin's[8] latest contribution to the philosophy of correlation; but though the principle is accepted there is still occasion to dwell upon *the constancy of erosion and the inconstancy of sedimentation,* especially since the facts may be the reverse of what is sometimes assumed and since they lie at the foundation of our interpretations of the geographic record.

[7] Newberry, J. S., "Circles of Deposition," Amer. Assoc. Adv. Sci., *Proceedings,* Vol. 22, pt. 2, 1874, pp. 185–196.

[8] Chamberlin, T. C., "Diastrophism as the Ultimate Basis of Correlation," *Jour. of Geol.,* Chicago, Vol. 17, 1909, pp. 685–693.

It is assumed in some instances that erosion on supposed subaerial surfaces has either not occurred or has left no traces, whereas on the other hand the surfaces, if they had been submarine, must invariably have been covered with sediment, which would constitute a record. And the conclusion is drawn that sections which exhibit an incomplete sequence of strata must have been land areas at certain times. It is a hazardous conclusion in the absence of definite evidence of erosion, for subaerial processes never fail to leave some kind of mark, and submarine processes are consistent with non-deposition.

Constancy of Erosion.—The atmosphere is never at rest. Wind, rain and snow; heat and cold; moisture, carbonic acid and other chemical agents; all these have ever worked unceasingly, according to the circumstances that condition them, upon exposed land surfaces. No land has ever been exempt from their attack, which results in decay, denudation or aggradation, as the case may be.

Decay, denudation and aggradation are processes of erosion which invariably leave chemical or mechanical evidences of their activity. There is to-day no surface of any land, however high or low, under any climate whatever, which does not bear indubitable marks of one or the other of these processes. There is abundant evidence that they have been at least equally active and effective during past ages and that they have marked ancient lands as they do those of to-day.

We frequently recognize ancient land surfaces on evidence of soils, wear or subaerial deposits. Or, if they have passed through processes, such as marine transgression, that destroy the earlier effects, we observe the sequence of changes and reason back to the corresponding conditions. But there are seemingly continuous sections

which are nevertheless apparently less complete than others in adjacent basins and which seem therefore to have been areas of non-deposition. Even if the hiatus be real, and not merely supposititious, it does not follow that non-deposition has been a subaerial condition. Such anomalies of non-deposition occur characteristically between strata laid down during periods of wide-spread marine transgression when lands were low and covered with residual or alluvial deposits. If any area was raised higher during the interval, it must have been correspondingly corraded. And if the evidences of decay or corrosion are wanting the postulate of a land area corresponding to the region of non-deposition should be regarded with much doubt.

Inconstancy of Marine Sedimentation.—It is commonly assumed that sediment of some sort necessarily accumulates over the bottom of a marine basin and that this has always been the case in epicontinental seas of all ages. Consequently non-deposition is not considered and special hypotheses of uplift and subaerial erosion are devised to account for the absence of strata which might or should have been deposited. Yet non-deposition and even the scouring of bottoms so that hard rock is exposed are conditions of modern sea bottoms where they are swept by currents whose load is less than their efficiency.

Verrill has described the coarse shifting sands of the New England coast, which are kept in such constant motion by tidal currents that no life finds lodgment on them. The whole continental platform from Long Island to Hatteras is so swept that sand alone comes to rest, all finer sediment being carried on to the zone of oceanic ooze.

Agassiz found hard limestone bared of any deposit except serpularia and similar clinging organisms beneath the silt-laden Gulf Stream, where it flows across the epicontinental platform, between Florida and Cuba. Among existing seas and straits this instance is one which, in the conditions for marine scour, most nearly resembles the epicontinental seas of past times.

Between Scotland and the Faroe Islands stretches the Faroe Island ridge, a wide stony bar between the North Atlantic and the Arctic basins. Its crest lies 300 fathoms below the surface of the ocean; yet it is swept clean, while banks of ooze accumulate on the slopes north and south of it.

The present distribution of lands and oceans is unfavorable to marine scour and favorable to deposition. Epicontinental seas are confined to the margins of continental platforms, to which high lands contribute abundant sediment, or they are deeply embayed and shut off, as Hudson Bay is. Non-deposition is therefore an exceptional condition. We may grant that it has always been restricted to comparatively shallow waters, in the path of a relatively strong marine current. But the epicontinental seas of the periods of great marine transgressions (Cambrian, Ordovician, Silurian, Devonian, Mississippian and Cretaceous of North America for instance) opened channels across the continent, through which oceanic currents circulated as the Gulf Stream flows from the Caribbean to the Atlantic. Low lands bordered these seas and the deposits which accumulated in the deeper basins consisted in great part of fine calcareous ooze. Under these conditions non-deposition and marine scour have been favored on shallows along shores and in straits, and in any such places a corresponding hiatus must occur in the stratigraphic sequence.

In paleogeographic study it is important, therefore, to consider the principle that marine waters may not only deposit sediment, but may also prevent deposition, or even remove a deposit previously made.

PRINCIPLES RELATING TO CLIMATE

The history of past climates affords problems which are among the most obscure of paleogeography.

On the one hand climate at any particular epoch has been determined by the distribution of land and sea and the corresponding movements of the winds and positions of the great cyclonic and anticyclonic centers. Given a map showing the oceans and lands of the northern or southern hemisphere, the climatologist may apply the principles deduced from the present relations of atmospheric activity to surfaces that affect the temperature of the atmosphere in different degrees and he may arrive at a reasonable conclusion in regard to the distribution of temperatures and precipitation.

Such a conclusion is based, however, upon existing climatic conditions and can be only a rough qualitative approximation to the very different conditions of earlier ages. The geologic record yields abundant evidence to show that our present climates are unusual in the extreme differentiation of climatic zones. No previous age offers evidence of equal polar refrigeration, and none has as yet shown proof of deserts of equal extent and general distribution. On the contrary, it would seem that climate in the past has been generally more uniform from pole to pole and around the earth than it is now.

We may attempt to explain this result of observation by recognizing that the present diversity of climates is connected with extreme conditions of mountain growth. Mountain ranges are to-day more general and of greater altitude than they have commonly been in the past and the condition of the low lands, which has at times prevailed over the greater part of the continent, has been favorable to uniformity just as the converse is favorable to diversity of climate. But this explanation falls far short of satisfying the requirements of the problem.

We may supplement the reasoning by appeal to the reversal of oceanic circulation suggested by Chamberlin as a possibility in view of the fact that equatorial saline waters, even though warm, might under certain conditions become denser than fresher polar waters, even though these be cold, and thus warm waters sinking in the equatorial regions and flowing toward the pole would carry with them the higher temperatures of the tropics and produce more genial climates in the polar regions. This suggestion is extremely attractive, and has a high degree of probability, particularly when we consider that the present circulation of deep-lying cold waters is largely due to the polar ice-caps, which are themselves extraordinary features. There is reason to believe that the present oceanic circulation is abnormal and the reversed circulation suggested by Chamberlin has in past ages been the normal condition.

In recognizing the effectiveness of low lands and reversed ocean currents to produce uniformity of climate such as the geologic record requires, we arrive at a working hypothesis which satisfies the immediate condition of certain climates that characterized great periods of the earth's history; but we are yet far from an understanding of the processes which underlie the change from one condition of climates to another. There is some general cause, so subtle that it has as yet eluded distinct recognition, which affects the conditions of climate more deeply than the local phenomena suggest. It has been approached by theories along astronomical lines and by a single theory which connects climate with the earth's internal forces.

The astronomical causes may be shown

to have an essential relation to climate, but at present I believe we can not fairly say that that relation has been shown to have existed. On the other hand, there appears to be a definite connection between the physical geography of the earth's surface and the climate of any corresponding epoch. Large continents and high lands have been associated with diversity of climate; small continents or archipelagoes and low lands have been associated with uniformly genial climates. Moreover, the chemical reactions between rock masses exposed to weathering and the critical constituents of the atmosphere and the seas, such as carbonic acid and moisture, appear to establish a chain of phenomena, which involve temperature and humidity, and which affect the intensity of provincial climatic differences. In a broad and general sense we may refer to the periodicity of climatic change in the same way that we recognize periodicity of general diastrophism, and the cycles of the one appear to coincide with the cycles of the other. Chamberlin has recognized the relation and has endeavored to trace it through the critical influence of the small percentage of carbonic acid in the atmosphere. In following the course of that critical element from the air through the laboratory of the lands and seas back to the atmosphere, he established a chain of phenomena which is unquestionably a *vera causa* of the common periodicity of the phenomena.

We may conclude then that the study of ancient climates involves two connected problems. The first relates to the distribution of provincial climates according to the distribution of lands, seas and permanent oceans. It may be approached by applying the laws of modern meteorology to a preliminary solution. That solution must, however, be tested against the geologic and paleontologic evidence of the corresponding time, and must be qualified by conclusions based upon broader principles which involve the physics and chemistry of the atmosphere in its relations to land and sea. Through these the second problem, which involves the periodicity of climates, is to be approached.

EVOLUTION AND ENVIRONMENT

In the long chain of causes and effects initiated by terrestrial and solar energy, the development of life is the latest link. All that precedes life is characterized by change which moves in a series of cycles. Life, on the other hand, is characterized by change which has moved forward in progressive evolution. Upon this fundamental distinction we separate the inorganic from the organic and recognize the latter as pertaining to a higher phase of development.

Evolution is not, however, the only attribute which distinguishes life from the lifeless, for life is qualified by the further attribute of death. The individual, the species, the genus, the family and race, everything which lives, ultimately comes to the final end, and there is in the evolution of the organic no return of that which has thus died. While the inorganic world repeats, the organic world never does.

Profound as these distinctions are, they nevertheless do not emancipate the organic from the control of the inorganic. Life is inexorably conditioned by its environment. Through ages of evolution and adaptation, each individual is fitted to exist under a special set of circumstances which constitute his environment. Narrow limits are set to the capacity of the organism to adjust itself to sudden changes, and only within those limits can it continue to exist. Beyond them on all hands stands the inevitable death. In the history of the individual there are special periods of

development, such as infancy, youth and old age, when these limits are narrower than they are for the epoch of full vigorous development of the adult; and these sensitive periods are those which are critical for the history of the species.

The influences which govern evolution have recently been stated by two of our great biologists, Jordan and Osborn. They both recognize that in the development of organic life the grip of environment holds.

Jordan,[9] dwelling on the importance of isolation as a factor in evolution, recently wrote:

> Among the factors everywhere and inevitably connected with the course of descent of any species, variation, heredity, selection and isolation must appear; the first two innate, part of the definition of organic life, the last two extrinsic, arising from the necessities of environment, and *not one* of these can find leverage without the presence of each of the others.

Osborn has put the same principle as follows:[10]

> The life and evolution of organisms continuously center around the processes which we term *heredity, ontogeny, environment* and *selection;* these have been inseparable and interacting from the beginning; a change introduced or initiated through any one of these factors causes a change in all. First, that while inseparable from all the others each process may in certain conditions become an initiative or leading factor; second, that in complex organisms, one factor may at the same time be initiative to another group of characters, the inseparable action bringing about a continuously harmonious result.

These modern statements of the law of natural selection find application immediately as we contemplate the procession of geographies. Change of environment is inherent in the movement of the procession down the ages and, cooperating with intrinsic biotic forces, has caused modification of organisms as a necessary consequence.

Environment as related to any species or to any flora or fauna may be said to be that combination of conditions to which the fauna is adapted and beyond which it can not range into other environments. From this follows the principle: *Except through renewed adaptation, an adapted fauna can migrate only as the limits of its habitat recede, as the area of its environment broadens.*

To apply this principle to the distribution and migration of species or groups of species under the general law of periodicity, we may follow the course of a cycle of changes, from an epoch of diverse conditions through a cosmopolitan state to diversity again.

Diverse conditions of any one geographic state may have been grouped simultaneously to form many environments or faunal provinces, and each of these has then been occupied by its peculiar fauna contemporaneously with more or less unlike faunas in other provinces. Each of these faunas represented an adaptation to the conditions of its peculiar environment. The peculiarities of other faunal provinces surrounding it constituted barriers beyond which the species could not live, or could not rear their young, even if the adults could exist under the adverse conditions. Only within those barriers could those specially adapted species long continue to exist. If their habitat became contracted they also must contract their range; if it shifted or expanded, they might migrate accordingly. And there would be corresponding migration or restriction of faunas which were diversely adapted. Any cause which shifted the conditions of light, heat or food, brought opportunity to some, death to others.

[9] Jordan, David Starr, Isolation as a Factor in Organic Evolution, in "Fifty Years of Darwinism," 1909, pp. 90–91.

[10] Osborn, Henry Fairfield, Darwin and Paleontology, in "Fifty Years of Darwinism," 1909, pp. 238–239.

In the circling changes of geography such an epoch of diversity has been followed by the development of more or less extensive uniformity, according to the periodicity of diastrophism. Let it be assumed that in the course of a long period of quiet, barriers yielded to the monotony of low lands, freely communicating seas, and genial cosmopolitan climates. The factors of evolution were then profoundly generalized. Isolation was replaced by intercourse, adaptation by competitive development and variation, restriction by opportunity. Success lay with him who had the intrinsic capacity to occupy and to hold the widening realm of life. Out of such conditions came cosmopolitan faunas, which exhibit closely similar or identical associations of species even though inhabiting widely separated regions. The identity may be due to *perpetuation of ancestral species,* which have followed up the movement of a favoring habitat; or it may result from evolution of a successful fauna, competent to spread throughout the wide kingdom to which it is born. In the one case the migrants may have lived simultaneously with descendants of the common ancestors in the home province, or the ancestral stock may have died out there before the migration was complete. *The time equivalent or coefficient of migration is indeterminate.* In the second case, that of *indigenous evolution,* the time elapsed while the species spread over an area which was everywhere geographically favorable depended only upon the ability of the migrant and may be assumed to have been brief as compared with geologic epochs. This is the usual assumption. It may be true for appropriate species and periods, but is by no means always true.

Cosmopolitan conditions have been truly world-wide only in exceptional cases. Very extended faunal provinces have been less rarely developed. The Arctic Ocean has been one which repeatedly expanded to include much of Eurasia and America. The girdle of ocean currents which encircled the world in the northern, temperate and tropical zones during Paleozoic, Mesozoic and Eocene times was another such province. Both of these became from time to time the homes of cosmopolitan faunas that existed simultaneously over surprisingly wide realms. At other times they were restricted or divided and faunas became provincial.

If we consider the course of evolution during an epoch when general conditions yielded to provincial environments (excluding the case in which the change is too drastic) the law which applies is Jordan's law of isolation. He uses that term to signify the separation of one or many individuals from others of their kind. The separation implies more or less diversity of environment and consequently more or less unequal or unlike variation along the many possible paths open to the living organism. We conceive a broad life realm, marine or terrestrial, which through subtle changes in the flow of currents of the sea, or of climates of the land, or of depth of waters, or of altitudes above the seas, or of any other condition affecting sensitive organisms, is divided into provinces which offer unlike environments to the descendants of the ancestral cosmopolitan fauna. Adaptation becomes again the dominant process. Being variously conditioned, it leads to variation and the development of different species.

North America represents the facts upon which Jordan[11] founded the law of twin species, which is that:

[11] Jordan, David Starr, Isolation as a Factor in Organic Evolution, in "Fifty Years of Darwinism," 1909, p. 73.

Given any species (or kind) in any region, the nearest related species (or kind) is not to be found in the same region, nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort.

This law, worked out by observation of existing faunas and based on their distribution in our highly diversified lands, owes its recognition to the fact that topography and climate have undergone great changes, and provincial environments have been individualized during the latest geologic periods.

The latest period to which we can assign fairly uniform conditions of climate and moderate relief in North America is the Miocene, and the diversity of environments developed since then is so great that there is reason for surprise at the persistence of geminate species. One might expect differentiation to a degree which would have obscured or obliterated twinship. But it appears that there are provinces in which variations of some ancestral species have not diverged greatly, presumably because conditions within these particular provinces have not undergone any very stimulating or very restrictive change, as regards those species. Such surviving varieties must indeed have existed to a greater or less extent during any such period of changing environments, and the persistence of geminate species must have been a feature of many epochs of diastrophic activity in the past. How long they may have persisted, how slowly or rapidly or impulsively they may have varied, we do not know. *The time relations of geminate species are therefore indeterminate.*

CORRELATION

Definition.—By correlation in paleogeography or geology, I understand that process of reasoning which seeks to demonstrate that certain events of past history occurred simultaneously.

Contemporaneity.—In dealing with the enormous time intervals of the earth's history the concept of simultaneous or contemporary events must be liberally grasped. A fair statement is that the phenomena described as contemporaneous shall have existed at the same time within limits of error which do not equal a large fraction of the life of either. Thus we call two men contemporaries when the periods of their active lives coincide, though one may have been born notably later and live longer than the other. But we do not so term a youth and a graybeard, whose living occupies but a few years in common.

It is evident that two long-lived events may differ from near coincidence in time by a larger margin than two short-lived events, and yet be reasonably regarded as contemporaneous. The marine transgression which submerged most of North America during the Cambrian was in a broad sense contemporaneously paralleled by submergence of much of Eurasia; but the moment of arrival of the earliest Cambrian fauna, the Olenellus, which followed the spreading shores over each continent, can not be regarded as contemporaneous at points reached earlier and later in course of the submergence.

The evidences of contemporaneity are both inorganic and organic, but, though we are wont to classify them thus in two distinct categories, they are most intimately related through that principle of periodicity, which is at the bottom of all terrestrial phenomena. Diastrophism is periodic, all changes in the inorganic as in the organic are conditioned by that periodicity, and all such changes are therefore themselves periodic. Moreover, the physical and biological phenomena are linked in a continuous chain of cause and effect, which stretches from gravity and internal heat at one end to life at the other, and which

tends ever to vibrate in harmony. Whatever disturbs the equilibrium of any part, affects the whole. Diastrophism initiates change. The sun's energy modifies the resulting surface features, and physical, chemical and biotic reactions carry the effects into all the phenomena of nature. Were nature unchanging, time would pass unrecorded. It is through the sequence of unlike *effects* that we may establish a chronology, and that sequence begins with diastrophism as the initial cause and ends with evolution as the final effect.

DIASTROPHISM THE BASIS OF CORRELATION

It follows logically from the preceding that the initial cause of change, diastrophism, is necessarily the ultimate basis of all correlation. Chamberlin[12] has very recently put this conclusion strongly and clearly.

On a preceding page the law of periodicity of diastrophism is stated as deduced from the observed occurrences of diastrophic movements in different dynamic provinces. According to that law it is *inactivity, rather than activity,* of earth movements, which has contemporaneously characterized the whole earth. That is to say, the normal condition of the stresses and resistances in the earth's crust is a close approach to equilibrium, and disturbances of that equilibrium have in general been manifested at the surface by slight movements only. More emphatic movements have been relatively occasional and provincial (circum-oceanic), and we may add that they have been more restricted and less prolonged as they have been more vigorous.

This law governs the relation of diastrophism to correlation.

The long eras of inactivity, the base-level eras for the whole world, have been essentially contemporaneous, though not conterminous or even approximately conterminous. But their very great duration, from which their essential contemporaneity results, unfits these eras for any except the broadest outline of classification, so far as they themselves are concerned. Yet the topographic, climatic and environmental uniformity which developed during these eras of inactivity affords the best conditions for correlation by other criteria. Thus the base-level eras are to the history of paleogeography what the broad and deep foundations of a great building are to the many rooms of the superstructure.

Thus for inactivity. The periods of activity present different phenomena, differently distributed in place and time. We may define a period of activity as comprising that time which is marked initially by decided continental movements and culminates in notable orogenic uplifts. Pennsylvanian and Permian constituted such a period about the North Atlantic, as witness the development of lands, mountains and sediments in western Europe and eastern North America. The recognized active periods appear to characterize distinct dynamic provinces which are ocean basins, as already described. Thus with regard to their value in correlation we may say: *Periods of active diastrophic movement have been shorter than eras of base-leveling, and consequently define time divisions, which are more nearly commensurate with those of current geologic standards.* They are, however, still long, and their value is in broad fundamental classification.

Diastrophic activity is, moreover, contemporaneously manifested only in and around the dynamic province in which it originates. During any particular period it has been peculiar to a particular oceanic basin or group of basins and has disturbed

[12] Chamberlin, T. C., "Diastrophism the Ultimate Basis of Correlation," *Jour. of Geol.*

only the continental masses adjacent to that basin or basins. The value of periodic activity in correlation is thus conditioned by the regional distribution of diastrophism.

Continents bordering on one and the same dynamic province have usually been disturbed during one and the same period. Opposite sides of one and the same continent, however, bordering on different dynamic provinces, do not exhibit similar conditions of disturbance at the same time.

Western Europe and eastern North America, for instance, exhibit parallel diastrophic histories, peculiar to the North Atlantic basin, but the diastrophic histories of the Atlantic and Pacific sides of North America do not run parallel.

Any great period of diastrophic activity, though relatively short as compared with an era of inactivity, is very long in comparison with any particular movement incidental to its own development. Thus Pennsylvanian and Permian diastrophism had a long history before the folding of strata occurred in the Appalachian trough. Such an incident of folding, or of any orogenic growth whatever, is locally conditioned. It results from local structures and localized pressures. The time of disturbance depends upon the local position of the district in relation to the source of disturbing stresses, and is peculiar to the district. The phenomena of folding, or of orogenic growth, therefore, do not afford criteria for correlation beyond the area of special conditions. We may not safely correlate the displacement of the Appalachian zone with the disturbance of the Carboniferous in England, for instance, although both events occurred during the same diastrophic period and belong to one and the same dynamic province.

Within any *orogenic district*, the epoch of general disturbance is a principal element of classification. It is set apart, it is unavoidable. It must be recognized, and it commonly separates major divisions.

This stated, it is none the less of the first importance to insist on the local character of the criteria. A district of orogenic disturbance is sharply limited by mechanical conditions. Across the line exist other conditions, which are inconsistent with orogeny and its manifestations. The criteria of correlation by orogeny fail, therefore, beyond the line. Disturbance and quiet, erosion and continuous deposition, unconformity and conformity, have developed simultaneously in immediately adjacent districts many times.

In strong contrast to continental and orogenic movements, which develop subaerially, are those subsidences which occur beneath the oceans. Though they also are more or less local, their effects are practically world-wide, for any submarine movement modifies the capacity of ocean basins and changes the position of sea level on all coasts. No other phenomenon is so nearly simultaneous.

If any one of the confluent ocean basins be deepened the sea level datum about all lands must be lowered. The effect may not be evident in the exceptional case that any land subsides by a due amount; but the exceptional case is not likely to mask the general effect of a universal ebb tide. Shallowed and reduced epicontinental seas, low islands and low coastal plains mantled with the latest sediments, slight erosion and unconformity without disturbance of the strata, constituting a general condition of continents, these are the characteristic phenomena of such an ebb. They distinguish the middle Ordovician of regions as remote as eastern North America, eastern China and western Europe. They mark also the passage from Cretaceous to Eocene.

Suboceanic movements have no doubt

occurred, especially during periods of pronounced continental deformation, but also during eras of quiescence on lands. Their effect upon sea level is, however, readily confused or masked by local uplift or depression and is, therefore, of little value when these become decided. During base-level eras the conditions for recognition are most favorable and the occasional occurrence of a world-wide ebb constitutes the most exact measure of contemporaneity by which we may correlate.

The several groups of diastrophic phenomena which have been outlined furnish the fundamental basis of classification and correlation. They are obviously very unequal in scope, character and value. Their geographic range may embrace the sphere, or fall within the realm of an ocean, or be no more extensive than a mountain district. Their duration may equal a vast era, or merely a period, an epoch or even only an episode. But all other phenomena are dependent and sequential. Diastrophism sets the stage and marks off the acts of the earth drama.

ORGANIC CRITERIA OF CORRELATION

I turn now to those criteria of correlation which are most universally employed, the criteria of organic evolution.

All paleontologists and geologists who are familiar with the geologic side of their science, as distinguished from the biologic, are convinced of the influence of environment on evolution; and they consequently recognize the dependence of species in regard to origin, development and distribution, upon the geographic conditions of their period of existence.

These extrinsic conditions have been by no means uniform from place to place or from time to time; they have varied periodically, and their influence upon life has differed in kind and degree according to the period. As has been emphasized by Chamberlin, marine life has at certain times been favorably conditioned by admission to broadening epicontinental seas, and alternately unfavorably conditioned by limitation to narrowed habitats on the margins of continental shelves. With similar effects terrestrial life has ranged over wide and connected continents under genial climates or has been confined to provinces of sub-continental or even smaller dimensions.

Marine life, when favored by extended domain, has also enjoyed genial and largely uniform environment. Shallow, freely communicating waters, traversed by continuous far-circling currents, offered uniformity. Barriers, whether of lands, or temperature, or sediment, or salinity, did not persist in marked degree at such times. Pressing against the shifting boundaries of his ancestral habitat, the marine migrant could advance as the limits receded, *no faster,* and thus a species fitted to compete in the occupation of new territory could spread from the provincial to the cosmopolitan with the corresponding spread of that environment to which it was adapted.

Assuming that the species persists during this time with only such variation as might be consistent with identification, the distribution will correspond to the spread of environment. The obvious fact is the presence of the species, or of the fauna, of one locality in another place also. The inconspicuous, but all-important fact is the control by the geographic factor, which has in any particular case determined a shorter or longer interval of migration. The migrants were descendants, who wandered as they could. That they could wander farther than their ancestors was due to a spreading sea, to the sweep of a marine current across a vanishing isthmus

or shallow, to a chilling or warming or other physical change, often as fatal to one fauna as it was favoring to another. The controlling factor was geographic; it set the hour of immigration; and through knowledge of it alone can we estimate the time elapsed during the wandering.

The case stated is that of passage from diversified to unified environments. It has repeatedly characterized geologic periods; and it has repeatedly culminated in the evolution and distribution of cosmopolitan faunas, which simultaneously peopled remote realms with like species. The coefficient of uncertainty, with which we must qualify any correlation that depends solely on identity of species, is reduced to a minimum at the time of culmination of uniformity.

Uniformity has in turn repeatedly yielded to diversity. Large marine faunal realms have been divided into provinces by emergence of continents, by diversion of ocean currents, by differentiation of climates, by local dilution or concentration of ocean waters and by the other changes which establish physical barriers. Lands have been diversified in like manner. In each such province evolution re-began by extinction of the unadapted and survival of the fitter forms. Originating in a common ancestry, the faunas of two neighboring provinces may for a time have had much in common. As they developed differences, Jordan's law of geographic isolation came into play. The resulting geminate species may have been closely contemporaneous; but continued contemporaneity depends upon uniform rates of differentiation, which the changing environments do not favor. Several relations, other than uniformity, are conceivable; isolate a fauna under static conditions and contrast it with the same fauna under changing conditions. Assume the changes to be favorable or unfavorable to the indigenous fauna. Contrast isolation with more or less free emigration and immigration. Consider the many factors of environment and the many possibilities of variation in sensitive, highly developed organisms.

Must we not conclude that diversity of species rather than likeness will be the rule at such a time among contemporaneous faunas?

But it is upon likenesses that we rest our faunal correlations. What do they signify? Simply that the surviving species of a fauna have remained unchanged during a longer or a shorter period, either at home or during migration, or that variations have developed similarly in two provinces from an ancestral stock similarly conditioned.

When we find a German fauna in New York or a Russian fauna in western North America, the occurrence means that the particular fauna persisted in an environment which offered it no stimulus to variation during the period of migration from the ancestral home to the new domain. But that period remains indeterminate. It was the shifting of the habitat that made the migration possible and that set the rate of progress. It was a geographic movement first and the faunal journey was a consequence.

Or in case of similar variations from an ancestral stock, can we assume that the stimuli acted in different provinces at the same times and at the same rates? When they did, but only when they did, were the similar variations contemporaneous; and the cases of such coincidence may reasonably be regarded as exceptional.

Hence I conclude that:

Correlation by identical or closely related species, faunules or floras is subject to a coefficient of error, which is a function

of the geographic changes of the particular period and of the geographic conditions that preceded.

The coefficient may be placed at a minimum, which is possibly negligible, at times of established cosmopolitan relations; but it rises to a quantity which we can not neglect at intervening periods of physical change.

The emphasis here placed on the geographic factor in correlation should not obscure the initiative part played by the life principle. It is the evolutionary force; its energy and the direction of its action depend upon the kind of organism. But the conditions of its action, its rate and the result depend upon environment at any instant and upon environmental change in the long run.

SUMMARY

The broad general principles of paleogeography, which I would cite as most fundamental, are as follows:

1. Ocean basins are permanent hollows of the earth's surface and have occupied their present sites since an early date in the development of geographic features. This principle does not exclude notable changes in the positions of their margins, which on the whole have encroached upon continental areas.

2. Superficial oceanic circulation within the permanent oceans has persisted since an early stage of their existence, essentially in the great drifts which it now follows under the trade winds. It is probable that the present deep circulation of oceanic waters, poleward at the surface and equatorward below the surface, is due to exceptional refrigeration at the pole, and has been preceded during past ages by a prevailing reversed movement of warm saline waters from the equator in the depths and cool less saline waters from the poles on the surface.

3. Diastrophism has been periodic. Viewed according to the periodicity of diastrophism, the earth's history falls into cycles, and each cycle into two periods, one of inactivity and another of activity. The periods of inactivity have been long, and during a major part of the duration of any such period the condition of inactivity has been common to the entire surface of the globe. Inactivity has not been coterminous, however, in different regions.

The periods of diastrophic activity have been relatively short, and as regards the whole surface of the earth in general not contemporaneous. The great ocean basins are distinct dynamic provinces, and each has experienced periods of diastrophic activity peculiar to its individual history. Orogenic districts are sharply limited by local mechanical conditions. The epochs of organic deformation are relatively brief. And folding and unconformity, therefore, are frequently not contemporaneous even in one and the same dynamic province.

4. The processes of erosion, sedimentation, chemical activity and organic evolution have been periodically conditioned according to the periodicity of diastrophism. The corresponding physical phenomena (relief, deposits and climate) exhibit rhythmic changes which repeat similar conditions in like associations. Organic forms, both faunas and floras, evolving through intrinsic vital energy but not repeating, have been rhythmically conditioned by changing environments.

5. Erosion has been constant on land surfaces through the activity of some of the sub-processes, decay, denudation or aggradation, which have never failed to make a record. A fossil sub-aerial surface must always show the record, unless it has been obliterated.

6. Marine sedimentation has sometimes been inconstant. During periods of dias-

trophic activity, when lands have been high, epicontinental seas small, and marine currents largely confined within deep ocean basins, sedimentation has been dominant. But during periods of diastrophic inactivity, when lands have been low, epicontinental seas extensive, and marine currents active on shallows and straits, sedimentation has failed in consequence of non-deposition or marine scour in appropriate situations.

7. The criteria of correlation are both physical and organic. The physical facts are basal. The organic forms, though endowed with evolutionary energy, are dependent and sequential. Any ultimate classification of the earth's history must be founded upon all the phenomena, interpreted through their relations in the chain of cause and effect from diastrophism to life.

Bailey Willis

A NATIONAL BUREAU OF SEISMOLOGY

At its last annual meeting, the American Philosophical Society showed its interest in the scientific investigation of earthquakes by devoting an entire session to their consideration. At the close of the session the following resolutions were unanimously adopted:

Whereas, Earthquakes have been the cause of great loss of life and property within the territory of the United States and its possessions, as well as in other countries, and

Whereas, It is only through the scientific investigation of the phenomena that there is hope of discovering the laws which govern them, so as to predict their occurrence and to reduce the danger to life and property, and

Whereas, Such investigations can be successfully conducted only with the support of the general government, be it, therefore,

Resolved, That this society urge upon congress the establishment of a national Bureau of Seismology, and suggest that this bureau be organized under the Smithsonian Institution with the active cooperation of the other scientific departments of the government and that this bureau be charged with the following duties:

a. The collection of seismological data.

b. The establishment of observing stations.

c. The organization of an expeditionary corps for the investigation of special earthquakes and volcanic eruptions in any part of the world.

d. The study and investigation of special earthquake regions within the national domain. And

Resolved, That copies of these resolutions be transmitted to the President, to the President of the Senate, to the Speaker of the House of Representatives and to the Secretary of the Smithsonian Institution.

Through the active interest of Dr. W. W. Keen, the president of the society, these resolutions were brought favorably to the attention of congress, and were in the House of Representatives referred to the Committee on Library, of which Honorable Samuel W. McCall, of Massachusetts, is chairman. The other members of the committee are E. L. Hamilton, of Michigan; Charles H. Burke, of South Dakota; William H. Howard, of Georgia, and Charles R. Thomas, of North Carolina.

Mr. McCall has already shown his appreciation of the importance of the subject, and it is hoped that readers of Science will lose no opportunity to urge upon their senators and representatives in congress the need of establishing such a bureau as is proposed, and to set forth the backward position of our government in this important matter as compared with foreign countries, though otherwise generously disposed towards scientific investigation.

There is already some danger that the matter may be disposed of through a small appropriation to some existing bureau, where the lack of special interest in the subject would soon result in the investigations being crowded out to make way for others which appeal more directly to the administration of the bureau.

Wm. H. Hobbs

University of Michigan

SCIENTIFIC NOTES AND NEWS

The national testimonial to Commander Robert Peary at the Metropolitan Opera House on February 8 was most enthusiastic, the house being completely filled. Governor

Hughes presided and a telegram was read from President Taft which expressed the hope that congress would take some substantial notice of Commander Peary's great achievement. Governor Hughes presented Commander Peary with a purse containing $10,000 which he immediately contributed toward fitting out an Antarctic expedition. A bill has been passed by the senate making Commander Peary a rear-admiral of the navy and placing him on the retired list.

THE Langley medal of the Smithsonian Institution, created in 1908 in commemoration of Professor Langley and his work in aerodromics, was presented to Messrs. Orville and Wilbur Wright on February 10. Dr. Alexander Graham Bell and Senator Lodge made addresses and Chief Justice Fuller presented the medals.

THE French Academy of Moral and Political Sciences has elected Professor William James, of Harvard University, a foreign member of the society, in the room of the late M. de Martens, of St. Petersburg. Professor James has been a corresponding member of the academy since 1898.

THE University of Cambridge has conferred the honorary degree of Sc.D. upon Dr. Mark Aurel Stein, explorer; and the honorary degree of M.A. upon the Rev. John Roscoe, missionary and anthropologist.

THE Academy of Natural Sciences of Philadelphia has appointed Professor Edwin Grant Conklin a vice-president, and Professor Ludwig von Graff, a corresponding member, as delegates to represent it at the eighth International Zoological Congress.

THE American Institute of Electrical Engineers has appointed Professor A. E. Kennelly president of the United States national committee of the International Electrotechnical Commission.

MR. CHAS. A. SCOTT, professor of forestry, Iowa State College, has been elected state forester for Kansas, under the provisions of a law enacted by the legislature of 1909. Previously he was for several years in the Forest Service of the United States Department of Agriculture.

DR. CHARLES B. DAVENPORT, director of the Station for Experimental Evolution of the Carnegie Institution, has given three lectures on "Heredity in its Application to Animal and Plant Breeding and to Man" at the Johns Hopkins University as follows:

February 7—"The Material Basis of Heredity."
February 8—"The Method of Inheritance of Characteristics."
February 9—"Heredity in Man."

THE students of Professor Spalding have set up a bronze tablet at the University of Michigan, bearing the following inscription:

VOLNEY MORGAN SPALDING

In commemoration of twenty-eight years of faithful service as teacher of botany in this university (1876 to 1904) and as a token of love and gratitude this tablet is erected by 100 of his former students.

Per naturæ opera mentem ad humanitatem fingebat atque virtutem.

Done in MCMIX.

The committee having the memorial in charge consisted of Professor L. R. Jones, Professor F. C. Newcombe and Dr. Erwin F. Smith.

DR. WILLIAM BRADLEY RISING, professor of chemistry in the University of California, died at his home in Berkeley on February 9 at the age of seventy years.

THE German Society of Scientific Men and Physicians will hold its eighty-second annual congress this year at Königsberg from September 18 to 24.

A CONVENTION of American Ceramic Societies was held in Pittsburgh on February 7, 8 and 9.

THROUGH DR. S. WEIR MITCHELL the College of Physicians and Surgeons of Philadelphia has received a gift of $75,000 from an unknown donor. The gift relieves the college from debt.

THE Tennessee Geological Survey will be established as a bureau of the state government, independent of any educational institution, with offices at the state capitol and with a director who will give his entire time to the work of the survey. Chancellor Jas. H. Kirkland, of Vanderbilt University, and President Brown Ayres, of the University of Tennessee,

are a committee of the board to select the state geologist and arrange other matters requisite for the inauguration of the survey. The annual appropriation is $15,000.

At a meeting of the board of managers of the National Geographic Society the following resolutions were adopted:

The National Geographic Society believes that it is of importance to science that tidal, magnetic and meteorological observations shall be obtained at or in the vicinity of Coats Land during the same period that the British expedition under Captain Robert F. Scott, R. N., is making similar observations on the other side of the Antarctic area, 1,800 miles distant, and at the same time that this recently discovered land shall be explored.

That the society is ready to accept Mr. Peary's proposition that it shall undertake jointly with the Peary Arctic Club an expedition to the Antarctic regions as outlined above, provided that the board of managers, after consultation with the members of the society, finds that the project will receive sufficient financial assistance to warrant the undertaking.

According to the daily papers, a delegation which included Dr. Ira Remsen, president of Johns Hopkins University; Brigadier General George H. Torney, surgeon general of the army; Dr. William H. Welch, president of the American Medical Association, and several others, have called on President Taft and urged the necessity for the cities of the country to adopt more scientific methods of sewage disposal. They asked the president to appoint a temporary commission to inquire into the matter. Mr. Taft said he was interested in the subject, but that he was without authority to appoint a commission.

During the summer of 1910 the University of Michigan Museum will be connected with three expeditions. As the depository of the state collections it will receive the specimens of the botanical investigations of a portion of the "peach belt" of Michigan, carried on by H. C. Kauffman and L. H. Pennington for the State Geological and Natural History Survey. Under a gift from Mr. Bryant Walker and an appropriation from the university the curator, Dr. Alexander G. Ruthven and Mr. H. B. Baker will make collections in southern Vera Cruz, Mexico, with the principal aim of enlarging the synoptic collection of molluscs and vertebrates. A third expedition financed by W. B. Mershon, Saginaw, Michigan, and to be known as the Mershon expedition will be sent to the Charity Islands, Saginaw Bay, Michigan, to continue the biological survey of the state that has been going forward for a number of years on appropriations from the state, university and private individuals.

UNIVERSITY AND EDUCATIONAL NEWS

Mr. Andrew Carnegie has promised to give to Cornell University the $50,000 required to enlarge Morse Hall, housing the department of chemistry.

The new biology building of the University of Wisconsin is to be placed on the upper campus, at the south end of the court of honor, between University and South Halls, facing the Lincoln statue. Originally plans were drawn to suit the site formerly chosen in the ravine between University and Observatory Hills. New plans appropriate to the new site will be prepared at once by the architects.

The New York *Evening Post* states that Mr. S. G. Iverson, state auditor, who recently made a thorough inspection of the school lands granted to Minnesota by congress in 1851, many years before the state government was organized, has compiled figures which show that the fund now amounts to more than $21,500,000, and that the state still holds approximately 3,000,000 acres of unsold land. These remaining lands have great wealth, fertile soil, abundance of growing timber, and the value of the iron ore deposits is almost beyond comprehension. "We have already 1,000 forty-acre tracts of land under mineral contracts in the iron-bearing districts," Mr. Iverson reports, "from which I believe we shall receive an average of 1,000,000 tons per forty, or a grand total of 1,000,000,000 tons, which, at a royalty of twenty-five cents a ton, the contract price, will produce the sum of $250,000,000. This endowment will be realized within fifty years, or before the state is a hundred years old. Of this sum I estimate that the school

fund will receive $170,000,000, the university fund $30,000,000, and the remainder will go to the swamp-land fund, the income from one half of which goes to the school fund and the remainder to assist in maintaining our state institutions."

A DEPARTMENT of experimental breeding has been established in the College of Agriculture of the University of Wisconsin by the regents, who have appointed Dr. Leon J. Cole, of the Sheffield Scientific School at Yale, an associate professor of experimental breeding. Dr. Cole will take up his new work with the opening of the second semester, conducting investigations in the subject of experimental breeding with special reference to the laws of heredity and improvement of animal life. He will also give instruction to advanced students. Dr. Cole graduated from the Michigan Agricultural College and the University of Michigan in 1901. He continued at Michigan as a graduate assistant for two years before entering Harvard University, where he obtained the degree of doctor of philosophy in 1906, and was appointed representative of the United States Bureau of Animal Industry in breeding work at the Rhode Island Agricultural College, whence he removed to Yale University in 1908.

THE Kansas State Agricultural College has established a new department, that of milling industry, and selected to head this department Mr. Leslie A. Fitz, now in the office of grain standardization, United States Department of Agriculture, and in charge of cooperative milling experiments and other work at the Fargo, N. D., Station. Mr. Fitz will enter upon his new field March 1. The object of the new department is to take cognizance more fully of the great importance of bringing to the market a more perfect grain and to investigate means of utilizing this to the greatest advantage. It will concern itself with all questions touching upon the wheat crop, flour making and bread baking. Mr. Fitz has been connected with the Department of Agriculture for several years and has been intimately associated with several lines of wheat investigation. He was also engaged in the same work previously at the Kansas State Agricultural College, of which institution he is a graduate.

E. K. SOPER, of Cornell University, has been appointed instructor in economic geology in the University of Minnesota.

MR. W. ASTON, M.A., demonstrator in physics, Birmingham University, has been appointed assistant to Sir J. J. Thomson in the Cavendish Laboratory, Cambridge. He is succeeded at Birmingham by Mr. E. E. Fournier d'Albe.

DISCUSSION AND CORRESPONDENCE

EARLIER REFERENCES TO THE RELATION OF FLIES TO DISEASE

IN the last number of SCIENCE (January 7) there is an interesting note by Dr. E. W. Gudger on Edward Bancroft's reference, in 1769, to the belief that flies transmit the tropical disease known as "yaws." It is not generally known that as early as the sixteenth century there was definitely promulgated the theory that flies play a rôle in the transmission of the plague.

Dr. Josiah Nott, 1849, lists Athanasius Kircher as among the earlier writers who believed that insects served as transmitters of disease. Dr. Kelly, in his fascinating volume "Walter Reed and Yellow Fever," goes further and quotes from Kircher's "Scrutinium Physico-medicum," published at Rome in 1658, the remarkable statement:

> There can be no doubt that flies feed on the internal secretions of the diseased and dying, then flying away, they deposit their excretions on the food in neighboring dwellings, and persons who eat it are thus infected.[1]

Unfortunately, Dr. Kelly's translation stops

[1] Apropos of the present-day belief that blood-sucking and stinging insects may occasionally be direct inoculators of disease germs, the following statement from the same work is of interest: "In a recent plague at Naples, while a certain nobleman was looking out a window a hornet flew in and lighted on his nose and stinging him with the sharp point of its proboscis, caused a swelling. And when the poison had gradually spread and crept into the vital organs, within a space of two days (without doubt from the contagious humours which the insect had sucked up from a corpse), he contracted the disease and died."

just short of Kircher's clause in which he attributes this theory to Mercurialis.

Mercurialis, a celebrated Italian physician, who lived from 1530 to 1607, was one of the encyclopædic writers typical of the period. I have searched the available volumes of his works, including several editions of his extended treatise on the cause and nature of the plague.[2] So far I have failed to locate the reference in question, but it is evident that Kircher was indebted to Mercurialis for the suggestion.

The statement of Mercurialis can be regarded as no more than a lucky guess, but to Kircher we must give more credit. This astute Jesuit, born in 1601, was an indefatigable worker, and his writings are much more than mere compilations. There is no doubt that long before Leeuwenhoek's discovery Kircher had seen the larger species of bacteria, which he described in the following words:

> It is known to all that decaying bodies abound in worms, but not until after the wonderful invention of the microscope was it found that all putrid substances swarm with an innumerable brood of worms which are imperceptible to the naked eye, and I would never have believed it if I had not proved it by frequent experiments, during many years.[3]

Among the substances in which he found these "worms" he mentions spoiling meat, cheese, milk, vinegar and decaying serpents. He does not stop with the mere discovery, but he attributes the production of disease to the organisms, and formulates a theory of the animate nature of contagion. Interpreted in this light, the statement of Mercurialis assumes a new dignity. The germ theory of disease, which became dominant so soon after this period, fell into disrepute, to be revivified in the latter part of the nineteenth century. Only now are we putting to the test the theory of Kircher relative to the rôle which flies play in the dissemination of disease.

[2] "De pestelentia in universum, præsertim vero de Veneta et Patavina," Venice, 1577.

[3] "Scrutinium Physico-medicum," 1658 ed., p. 42. This is one of many references which might be cited. In his book "Ars magna lucis et umbræ," published twelve years earlier, there is to be found mention of these "worms," showing that Kircher's observations really had extended over "many years."

Wm. A. Riley
Cornell University

SCIENTIFIC BOOKS

A Treatise on Zoology. Part IX. (Oxford Zoological Series). Vertebrata Craniata. First Fascicle—Cyclostomes and Fishes. By E. S. Goodrich. London, Adam & Charles Black. 1909. Pp. 518, 515 figs.

This is an advanced hand-book, scholarly in treatment and brimful of facts, bringing up to date the knowledge of a growing subject. It embodies also a number of original results which for the most part are based upon anatomical data: its facts are marshalled convincingly: many of its sections are admirably treated, especially those on the theme of bone, paired-fins and urogenital system. It considers fishes fossil as well as recent: its weakest side is its treatment of the results of embryology. The illustrations are numerous, usually well selected, scores of them original and important. From the book-making standpoint, the work is the equal of those which have preceded it in the Oxford series: among details one may be mentioned which may seem trivial to a strong-wristed reader—the paper, though apparently heavy, does not weigh pounds as in the case of several hand-books newly published in the United States.

Goodrich's book, in a word, is a very valuable contribution, and its preparation must have proved a formidable task. Weak spots it has, however, and reviewers will not fail to discover them. The fact is one should hardly expect that a single writer could follow the literature of so broad a subject without an occasional slip. As it is we may safely say that Goodrich has accomplished a conspicuously better task than any of his predecessors. We may pass over proof errors, which are not rare but of the usual type, and as we thumb over the pages point out such defects as these: "Myxinoids are normally hermaphrodite," the author not knowing, apparently, that the early findings in this matter are discredited. *Læmargus,* the great Greenland shark, does not "fertilize the eggs externally" as Turner

and Lütken believed. Jungersen has shown conclusively that these early findings were based upon immature specimens. I know of no trustworthy evidence that the whale-shark "realizes the length of some seventy feet": it probably does not exceed fifty feet or thereabouts. There is, as far as I am aware, *no* "embryological evidence that the hyomandibular element in *Holocephala* has fused with the skull." The early forms like *Pterichthys* are not, I am convinced, separated from Coccosteids on the grounds which are instanced, pp. 260–261, though this is a matter upon which opinions of specialists may differ. "*Palæospondylus* can not be a larva on account of the centra present," but it is none the less a fact that larval forms, fish or amphibian, are not uncommon in which well-grown centra are present. Goodrich again assumes a "pineal eye" in petromyzonts, though it is only fair to admit that this organ may not *sensu stricto* be an eye at all, perhaps it is a temperature-appreciating organ, for one can hardly call an organ an "eye" in which a dense screen of pigment separates the image—if there be an image—from the sensory cells. On page 125 we read that "the main lateral line of the trunk runs forward on to the head": a better reading perhaps would have been that the main lateral line runs backward from the head, in view of the development of this organ. It is stated that the "yolk-sac of the Selachian protrudes from the ventral surface of the embryo often after birth," a condition which, I believe, does not normally occur. At least I have observed that in six species (in three different families) the young show at birth nothing more conspicuous than a scar to mark the disappearance of the sac.

In several details of terminology I am not sure that Goodrich has lessened our troubles. In certain cases he has created a series of popular names for groups whose technical names are already widely accepted, in some cases classic. Thus why should we adopt "Petromyzontia" and "Myxinoidea" for the well-known Müllerian names Hyperoartia and Hyperotreta? Nor is he consistent in his effort toward popularization, when he devises complicated technical names where simpler ones seem adequate. Thus in the matter of the fin supports of fishes he usually discards the well-known "radials," "basals" and "actinotriches" (or plain "dermal rays," to distinguish them from obvious skeletal rays), for such new names as "dermoptrichia," "somactidia," "lepidotrichia." Indeed it is not quite clear that these terms are as specific as the author implies. We query whether the criterion of their homology is to be based upon the details of structure instanced, for we recall that the homology of the bones of teleosts can not be determined on such finely-spun histological distinctions. Indeed, Goodrich himself reverts to the homely "radials" and "basals" when he is not on his guard (p. 302). He occasionally uses names for various structures which are far more questionable in point of homology than the fin supports noted above. Thus he refers throughout to "clavicle," "coracoid" and "scapula" in fishes, although specialists by no means agree as to their homologies in the cheiropterygian girdle.

His treatment of the teleosts will not escape criticism. Certain it is that he has cut several of the Gordian knots in which the despairing phylogenist has been entangled. Thus, undaunted by convergence, he adopts numerous (about twenty) group-names ending in "formes"—Notacanthiformes, Perciformes, Beryciformes—and from this point of view gives us a very useful summary of the groups, perhaps the best of its kind. This mode of treatment has clearly the merit of convenience—too great convenience, perhaps, for we doubt whether it expresses adequately our present knowledge of teleostean interrelationships.

BASHFORD DEAN

A Hand-list of the Genera and Species of Birds. (Nomenclator Avium tum Fossilium tum Viventium.) By R. BOWDLER SHARPE, LL.D., Assistant Keeper, Department of Zoology, British Museum. Volume V. London, printed by order of the trustees. Sold by Longmans & Co., 39 Paternoster Row,

E. C.; B. Quaritch, 11 Grafton Street, New Bond Street, W.; Dulau & Co., 37 Soho Square, W., and at the British Museum (Natural History), Cromwell Road, S. W. 1909. All rights reserved. 8vo, pp. xx + 694.

The issue of Volume V. of this great work, late in 1909, brings to a conclusion an undertaking of the greatest importance to systematic ornithologists. The first volume appeared in 1899, the second in 1900, the third in 1901 and the fourth in 1903, the whole comprising about 1,700 pages. The work is similar in plan to the late C. R. Gray's "Handlist of Birds" (3 vols., 8vo, 1869–71, British Museum), being a list of not only the genera and species, but of the higher groups, in systematic sequence. The classification followed is that proposed by Dr. Sharpe in 1891. No one could have had a better equipment for the preparation of such a work than its lamented author,[1] who wrote the greater part of the British Museum "Catalogue of Birds," and under whose supervision the whole (27 vols., 1874–98) was prepared and published, and whose knowledge of the external characters of birds and the literature of ornithology was doubtless unequaled by that of any ornithologist the world has yet seen. His "Handlist" is thus superior, in both method and detail, to any of its predecessors in the same field.

Under the genera references are given to preceding works where the group is monographically treated, and under the species to the British Museum "Catalogue of Birds," where full descriptions and citations of the principal references are given, or, in the case of species published since the appearance of the "Catalogue of Birds," to the original place of description; there are also often references in footnotes to authorities who have recently expressed opinions regarding the status or proper nomenclature of certain forms different from those adopted in the text. In order to secure the greatest degree of completeness and accuracy attainable, Dr. Sharpe sought the cooperation of leading authorities throughout the world, to whom he sent proof sheets of the work for revision. These correspondents numbered nearly thirty, of whom more than a fourth are residents of the United States. The work thus carries a degree of authoritativeness that could have been obtained in no other way, in respect at least to its minor details.

In judging a work of this character, it is important to know the view point of the author, especially with reference to the nomenclatorial standpoint and the species question. Unfortunately Dr. Sharpe was one of the few ornithologists of the older school who were unable to accept the modern idea of subspecies, and hence all the forms he has seen fit to recognize are catalogued as full species, the binomial form of names being strictly adhered to throughout the work. Hence many forms originally proposed as subspecies, and so recognized by later authorities, together with many discarded even by their proposers, are here catalogued as full species and stand on an even footing with forms of far higher taxonomic value. Their real status and relationships, or even the real worthlessness of many, are thus concealed from all but experts on the particular groups to which such forms respectively belong. While Dr. Sharpe thus catalogues "18,939 species," this number, it should be remembered, includes all currently recognized "forms" of birds, but many of them are not "species" in the commonly accepted sense, which probably do not exceed 13,000.

The nomenclature adopted is also, unfortunately, not in accord with the requirements of now commonly accepted rules. At the time when the early volumes of the British Museum Catalogue of Birds was prepared, the British Association Rules of Nomenclature, promulgated in 1842, were the only rules then in vogue, so far as rules of nomenclature were then respected. These rules provided that zoological nomenclature should date from 1766, or from Linnæus's twelfth edition of his "Systema Naturæ." Later the tenth, or 1758, edi-

[1] Dr. Sharpe died on Christmas Day, 1909, after a short illness, from pneumonia, at the age of sixty-two years.

tion of this work gradually became the generally recognized starting-point, and of late years has become officially so recognized in all modern codes of nomenclature. In the meantime the British Museum Catalogue had reached completion on the old basis, and a strongly grounded spirit of conservatism compelled adherence to the practises of earlier days. Hence we have in the "Hand-list" a work that, while of the highest utility as a catalogue of the genera and "species" of birds, is out of touch at many points with modern ways; but, with this fact in mind, the specialist can easily avoid the pitfalls. It should hence be remembered (1) that names, generic or specific, founded before 1766 (except Brissonian names) are here ignored; and (2) that emended forms of names are employed where a name as originally propounded is believed to have been incorrectly constructed.

It is with the greatest regret that, in reviewing the "Hand-list" from the present generally accepted standpoint of nomenclature, these criticisms seem necessary. No one can have a greater admiration for Dr. Sharpe's work in systematic ornithology than the present reviewer, who regards him as without a peer in his special field of activity, and his "Hand-list" as a fitting close to a long series of monumental works in ornithology.

J. A. ALLEN

Anfangsgründe der Maxwellschen Theorie verknüpft mit der Elektronentheorie. By FRANZ RICHARZ. 8vo, pp. ix + 245. Leipzig, Teubner. 1909.

This book, developed from a course of lectures to teachers, assumes on the part of the reader a knowledge of elementary experimental and theoretical electricity, as well as some acquaintance with analytical mechanics, potential theory and differential equations. It is not intended as in any way a complete exposition of electrical theory, but aims, and with success, to treat clearly and with precision a number of fundamental subjects, ranging from simple problems in electrostatics to the electromagnetic theory of light in media at rest. The treatment, while exact and of necessity involving many equations, is physical rather than mathematical. In the opinion of the reviewer it would be improved by making less use of potentials. Considerable use is made of dynamical and thermal analogies, and the electron theory is in evidence throughout, contributing much to the interest of the work. But few statements in the text are in need of correction. According to one of these *true* magnetism (div μH) corresponds to the magnetic pole strength of experimental physics, although a virtual modification of this statement occurs a little later. Also the electromotive force of a generator supplying power is referred to as the potential difference between its terminals on open circuit—an old error of remarkable vitality. The reviewer often wonders what one who defines the electromotive force of a generator in this way thinks about a series dynamo, for example, whose electromotive force for normal current may be thousands of volts, while its terminal potential difference on open circuit is practically nothing. According to another statement of the author, no direct experimental proof had been given, when the book was written, of the development of an electric intensity in an insulator by a changing magnetic field—the converse of the Rowland effect. It will be remembered, however, that such a proof was given some years ago by the experiments of Crémieu, as correctly interpreted by Larmor and H. A. Wilson. With only a few oversights in need of attention, the work as a whole is very free from errors. The printing is excellent.

S. J. BARNETT

SCIENTIFIC JOURNALS AND ARTICLES

THE opening (January) number of Volume 11 of the *Transactions of the American Mathematical Society* contains the following papers:

H. F. Blichfeldt: "Theorems on simple groups."

Virgil Snyder: "Infinite discontinuous groups of birational transformations which leave certain surfaces invariant."

E. B. Lytle: "Proper multiple integrals over iterable fields."

C. F. Craig: "On a class of hyperfuchsian functions."

W. D. Macmillan: "Periodic orbits about an oblate spheroid."

The December number (Volume 16, number 3) of the *Bulletin of the American Mathematical Society* contains: Report of the Princeton Colloquium of the society, by Virgil Snyder; Report of the September meeting of the San Francisco Section, by C. A. Noble; Report of the Winnipeg meeting of the British Association, by J. C. Fields; Report of the Salzburg meeting of the Deutsche Mathematiker-Vereinigung, by E. Dintzl; "Gergonne's pile problem," by H. Onnen; "The integral equation of the second kind, of Volterra, with singular kernel," by G. C. Evans; "Descriptive geometry" (review of recent works by Müller, Loria-Schütte and Wilson), by Virgil Snyder; Review of Jackson and Milne's First Statics and Martin's Text-book of Mechanics, by F. L. Griffin; "Shorter notices": Beltrami's works, by Eduard Study, Laplanche's Etudes sur les angles imaginaires and Thomae's Bestimmte Integrale und die Fourierschen Reihen, by J. B. Shaw; "Notes" and "New Publications."

The January number of the *Bulletin* contains: Report of the October meeting of the society, by F. N. Cole; "Note on the groups generated by two operators whose squares are invariant," by G. A. Miller; "The solution of the equation in two real variables at a point where both partial derivatives vanish," by L. S. Dederick; "Tables of Galois fields of order less than 1,000," by W. H. Bussey; "Bôcher's Integral Equations," by G. A. Bliss; "Shorter notices": Pasch's Grundlagen der Analysis, by F. W. Owens; Bennecke's Zweidimensionale Logarithmentafel, by E. J. Townsend; Young and Jackson's Elementary Algebra, by E. B. Lytle; "Notes," "New Publications."

The February number contains: Report of the meeting of the Southwestern Section, by O. D. Kellogg; "Note on a new number theory function," by R. D. Carmichael; "Baire's Lecons d'Analyse," by E. R. Hedrick; "Infinite series" (review of Nielsen's Unendliche Reihen), by J. B. Shaw; "The collineations of space" (review of Sturm's Geometrische Verwandtschaften, Volume III.), by Virgil Snyder; "A synoptic course for teachers" (review of Klein's Elementarmathematik, Volumes I. and II.), by J. W. Young; "Correction"; "Notes"; "New Publications."

THE FORTY-FIRST GENERAL MEETING OF THE AMERICAN CHEMICAL SOCIETY

The forty-first general meeting of the American Chemical Society was held in Boston in connection with the annual winter meeting of the American Association for the Advancement of Science, December 28–31, 1909. Nearly 600 chemists were present, making this the largest meeting ever held by the society.

On Tuesday, December 28, excursions were made to the breweries of Massachusetts Breweries Company and to the factories of Walter Baker & Co., chocolate and cocoa preparations, the New England Gas & Coke Co. and the Forbes Lithograph Manufacturing Co. In the evening the members enjoyed a complimentary smoker given by the members of the local section at the Hotel Brunswick.

On Wednesday the members of the society went to Cambridge, where a general meeting was held in the New Lecture Hall of Harvard University. They were the guests of the university at lunch at the Harvard Union. The following papers were read:

Report for the International Committee on Atomic Weights: F. W. Clarke.

Methods Employed in Precise Chemical Investigations: T. W. Richards.

On the Constitution of Curcumine—the Coloring Matter of Tumeric: C. Loring Jackson and Latham Clarke.

The Application of Physical Chemistry to the Study of Oleoresins: Charles H. Herty.

The Function of Chemistry in College Education: Lyman C. Newell.

The Cause of Color in Organic Compounds: Richard S. Curtiss.

The United States Pharmacopœia and the American Chemical Society: Joseph P. Remington.

J. A. R. Newlands: Chas. E. Munroe.

The Past and Future of the Study of Solutions: Louis Kahlenberg.

The Chemist's Place in Industry: A. D. Little.

In the evening the president of the society, Dr.

W. R. Whitney, gave an address on "Some Chemistry of Artificial Light."

Thursday and Friday the different divisions and sections met in the Lowell Building of the Massachusetts Institute of Technology. Two special features were a symposium on the Chemistry of Paint in the Division of Industrial Chemists and Chemical Engineers and a meeting of a special section to consider the Chemistry of India Rubber. The regular subscription banquet was held Thursday evening at the Hotel Somerset.

On Friday excursions were made to Lawrence, Mass., where the Wood Worsted Mills, the Water Supply and Sewage Experiment Station of the State Board of Health, and the New Water Filtration Plant were examined and the Fore River Ship Building Co. and the Distillery of Felton & Son, Inc.

DIVISION OF INDUSTRIAL CHEMISTS AND CHEMICAL ENGINEERS

A. D. Little, *Chairman*
B. T. B. Hyde, *Secretary*

Losses in the Storage of Coal: HORACE C. PORTER and F. K. OVITZ.

The organic matter of coal readily takes up oxygen from the air at ordinary temperatures and the coal thus deteriorates during storage in the air. The amount of this deterioration as determined by a laboratory study was found to be small (1.0 per cent. or less) when the coal was confined in bottles and a current of air passed through. It proved to be somewhat larger (over 2.0 per cent.) in the case of Illinois coal exposed to the outdoor weather. Deterioration was shown to be practically nothing during under-water storage for one year in the laboratory.

Immediately after mining coal absorbs oxygen rapidly. In one case 10 kilos exhausted the oxygen from 10 liters of air in four days. Only a very slight amount of CO_2 was formed during this oxidation. Methane, however, is exuded from freshly mined coal in considerable quantities and continues to be produced in some cases during long periods. The quantities of methane evolved are not sufficient to lower appreciably the heat value of the coal, but are of importance in producing explosive mine gas. The relative amount evolved by each coal conforms to the known gaseous character of the mine from which the coal was taken.

Outdoor tests are now being carried on by the U. S. Geological Survey in cooperation with the U. S. Navy and at the Isthmus of Panama to determine loss of heat value in coal stored in the open air as compared to that in under-water storage. Outdoor tests on Wyoming sub-bituminous coal showed a loss of five per cent. of the heat value in eight months open-air storage.

The True Melting Point of Trinitrotoluene: A. M. COMEY.

The accepted melting point of α-2-4-6 trinitrotoluene is 82°, but previous determinations vary from that figure down to 78.8°.

Careful melting point determinations were made on samples of C.P. trinitrotoluol obtained from various sources, and preparations of this substance were made in the laboratory from purified C.P. toluol, with the result that 80.5 to 80.6° was obtained as the corrected melting point in every case.

Bacterial Activity as a Corrosive Influence in the Soil: RICHARD H. GAINES.

Casting about for a theory to account for corrosion of iron and steel structures which are embedded in the soil, scientists are now giving consideration to the rôle played by bacteria. Recent work has shown that decompositions hitherto unsuspected and chemical changes in the soil are especially destructive to the iron. It has been found that acid contributions of the soil which have formed in abundance as a result of bacterial activity contribute to a large degree to the corrosive influences present. This corrosion is now known as shell rust and is often seen on steel or iron conveying pipes running through marshes or under water. Microscopic inspection of this rust shows that bacterial organisms have done the work. The following remedy for the evil was proposed: (1) Free drainage carrying off the acid solutions, (2) in localities where drainage is impossible slack lime should be packed about the metal, to neutralize acids formed as a result of bacterial activity.

Paint Films as Accelerators to Corrosion of Iron: W. H. WALKER.

Although the tendency to corrosion in iron or steel varies greatly with the condition of its manufacture, and although some samples are inferior to others, the fact remains that all iron and all steel will rust, hence the necessity of the study of the available methods of protecting such structures and the most general way is by paint. Any substance which will absorb, or combine with hydrogen, will on this account accelerate corrosion if such substance be in contact with iron. Linseed oil in its natural condition does this, and

that is why when such oil film is completely oxidized it ceases to accelerate corrosion. The influence of various pigments when they form parts of a linseed paint were discussed, and a method for quantitatively measuring this influence was described. It is believed that a development of this method may show much concerning the properties of ordinary protecting paint.

A Convenient Method of Refrigeration: J. O. Handy.

Liquid air is most convenient for temperatures below — 80° C. It costs $4 per liter and there are losses and possible breakages of containers which make its use in most cases expensive.

Carbon dioxide is satisfactory down to — 78° C. It is inefficient if used as a gas and not very satisfactory when used as the solid CO_2 snow.

The CO_2 snow dissolves freely in acetone alcohol, ether, gasoline and several other solvents of low freezing point. These solutions absorb heat rapidly from objects placed in them. They are perfectly mobile and easily handled.

Liquid carbon dioxide costs about 10 cents per pound. Three and one third pounds of liquid yield one pound of solid in two minutes if blown from the original container through canvas bags.

A mixture of 50 grams of CO_2 snow and 150 grams of acetone had a temperature of — 63° C. and caused one pound of mercury (freezing point — 39° C.) to congeal in two and one half minutes.

This method of refrigeration is useful for freezing tests of oils, for condensation of volatile substances, for precipitation of substances like paraffine from oil distillates and for general research work.

The Present Conditions of the Birch Oil Industry in the United States: Edward Hart.

The industry is one of those classed by the census takers as neighborhood industries and is carried on for the most part in the Appalachian plateau. The birch wood (*Betula lenta*) is cut into short pieces and distilled with water in primitive stills. About 50,000 pounds are produced annually. Oil of wintergreen (*Gaultheria procumbens*) is produced in the same way to the extent of 5,000 pounds. Illustrations of the stills and samples of the oil were shown.

Variations in Car-painting Practise: Carl F. Woods.

The four fundamental operations in car painting are filling the pores of the wood, smoothing down the natural inequalities of the surface, putting on the color in a smooth homogeneous film and finally covering the surface with a film of varnish. The three methods are the "lead and oil," the "surfacer" and the "color and varnish" processes. The advantages and disadvantages of the different methods are discussed. It is probable that no one of the methods embody the maximum efficiency but it has been shown that a saving of $20 to $30 can be made on the painting of each car and an increase in life obtained of from five to ten years by the adoption of scientific methods of finishing.

Some Variations in the Official Determination of Volatile Matter in Coal: A. C. Fielder and J. D. Davis.

Experimental data obtained in two different laboratories bearing on the variations in the volatile combustible matter, as determined in the official method of the American Chemical Society, are given in this paper, from which the following conclusions are drawn:

Laboratories using natural gas are apt to get results on volatile combustible matter that are considerably lower than those obtained in laboratories using coal gas unless the following precautions are observed: (1) Gas must be supplied to the burner at a pressure of not less than ten inches of water; (2) natural gas burners admitting an ample supply of air should be used; (3) air should be adjusted so that a flame with a short well-defined inner cone is produced; (4) the crucibles should be supported on platinum triangles and kept in a well-polished condition; (5) semibituminous coals should be placed in an inclined position across the corner of the bottom of the platinum crucible, to prevent the swelling up of the coke in the early stages of the heat treatment.

Results by destructive distillation in a small iron retort are practically the same as the official volatile matter in the coal.

Two laboratories may expect to vary as much as 2 per cent., both using the official method.

The following papers are reported by title:

Practical Corrosion Tests of Iron: W. D. Richardson.

Methods for Testing Commercial Anhydrous Liquid Ammonia and Results: W. D. Richardson.

The Temperature Reaction of Oil Mixtures with Sulphuric Acid: W. H. Boynton and H. C. Sherman.

A Comparison of the Accuracy of Different Formulæ for Calculating Fuel Values: H. C. Sherman and D. A. Bartlett.

Action of Liquid Anhydrous Ammonia on Rubber Gaskets: CHARLES H. EHRENFIELD.

A Simple Viscosimeter: CHAS. S. PALMER.

Lubrication, Lubricants—Oils, Greases and Solids: C. F. MABERY.

The Oxidation of Iron and Steel and how to Prevent it: J. S. STAUDT.

The Effect of Non-Metallic Impurities on the Properties of Steel: HENRY FAY.

New Methods of Asphalt Examination: ALBERT SOMMER.

A New Precision Centrifuge: H. E. HOWE.

Guayule Grinding Experiments: CHAS. P. FOX.

Incompatibilities in Chemical Manufacture: J. T. BAKER.

An Adiabatic Calorimeter for Use with the Calorimeter Bomb: FRANCIS G. BENEDICT and HAROLD L. HIGGINS.

The Weathering of Coal: S. W. PARR.

A New Gas Calorimeter: S. W. PARR.

Manufacture of Oxide of Zinc: GEO. C. STONE.

Scientific Preparation and Application of Paint: G. W. THOMSON.

The Determination of Oil in Flaxseed Products by the Specific Gravity Method: CHAS. A. HERTY and E. J. NEWELL.

DIVISION OF PHARMACEUTICAL CHEMISTRY

A. B. Stevens, *Chairman*

B. L. Murray, *Secretary*

Gamboge: F. O. TAYLOR.

Different adulterations of pipe and powdered gamboge are referred to and analytical results for starch tests, ash, alcohol solubility and acid value on fifteen samples are given. The value of the different tests and their indications, directly and by comparison, are discussed. The alcohol solubility is stated to be an unusually good means of detecting adulteration and the inclusion of a starch test in the U. S. Pharmacopœia specifications is recommended.

The Melting Point of Aconitine: F. O. TAYLOR.

Attention is called to the double melting point given by the U. S. Pharmacopœia and to the variation in this constant as recorded by different authorities. Results of 35 determinations confirm Dunstan's results of 188.5° and show that the melting point may be seriously affected by the manipulation employed. It appears that a statement of the melting point without reference to apparatus or method used is misleading and the need of some definitely stated process in the U. S. Pharmacopœia is emphasized.

Pharmacopœial Tests for Ammonium Benzoate: ATHERTON SEIDELL and GEORGE A. MENGE.

The only pharmacopœial tests for ammonium benzoate which might be expected to indicate the purity of the salt are the melting or decomposition point, and the litmus paper test for free acid. Both of these tests are shown to be unsatisfactory. In the case of the first, the decomposition point curve is almost horizontal for samples varying between pure ammonium benzoate and containing 50 per cent. of benzoic acid. The litmus paper test will not show the presence of 8 per cent. free benzoic acid. The quantitative analysis of the salt by distillation of its ammonia is recommended in preference to the "formaldehyde method" for the acid radical, although the latter method is to be preferred for the majority of the pharmacopœial ammonium compounds.

The Purity Rubric and the U. S. Pharmacopœia Tests with Notes on Quantitative Methods for Certain Pharmacopœial Compounds: ATHERTON SEIDELL and M. I. WILBERT.

The purity rubric of the U. S. Pharmacopœia is not always accompanied by satisfactory quantitative methods to determine the exact per cent. of purity of a given compound. The desirability of having satisfactory and withal simple methods of assay is generally accepted and in this paper a method for the quantitative determination of mercury is outlined, also a method for the determination of iodine as iodide. Several additional quantitative methods are referred to more briefly to illustrate the possibility of adapting more or less well-known quantitative methods of assay to pharmacopœial compounds and thus enhance the practical value of the purity rubric.

The following papers were reported by title:

Scope of Pharmaceutical Chemistry: A. B. STEVENS. (Chairman's address.)

Strychnine Sulphates: A. B. STEVENS.

The Botanical Source of the Crude Drug Known as Wild Yam: H. H. BARTLETT.

On the Availability of "Idophenine" in the Separation of Acetanilid and Acetphenetidin: W. O. EMERY.

Detection of Colocynth Seed in Powdered Colocynth: V. K. CHESNUT.

Pancreatin: JOHN P. STREET.

The Relation of the Chemist to Proprietary Medicines: W. A. PUCKNER.

Geo. D. Rosengarten, chairman of delegates of the American Chemical Society to the Pharma-

copœial Convention, led a discussion in regard to matters to be settled at that convention and received suggestions in regard to the policy that should be followed.

DIVISION OF PHYSICAL AND INORGANIC CHEMISTRY

Charles H. Herty, *Chairman*

Wilder D. Bancroft, *Secretary*

Ionization of Salts in Mixtures with No Common Ion: Miles S. Sherrill.

That the mass-law does not hold for the ionization of salts is well known. A thorough examination of data relating to the ionization of salts present in water alone and mixed with other salts has led to the formulation of the following general principle.

For any salt the ratio of the product of the concentration of its ions to the concentration of its un-ionized part is a function of the total equivalent ion-concentration in the solution and of that alone.

This rule, originally stated by Arrhenius as applicable to uni-univalent salts and extended by A. A. Noyes to include salts of higher types, has already been confirmed by various investigators through conductance measurements of mixtures with a common ion.

The conductivity of solutions containing definite mixtures of potassium sulphate and sodium chloride was measured and compared with the conductivity calculated with the help of the above stated principle. The agreement confirms the validity of the principle.

Ionization of Salts in Mixtures with a Common Ion: W. C. Bray and F. L. Hunt.

The experimental verification by conductance measurements of the principle given in the preceding abstract has been confined to mixtures of salts in which neither component was present in large excess. By taking advantage of the high mobility of hydrogen ion, an extreme case has now been investigated, viz., dilute solutions of HCl in the presence of large excess of NaCl. For each mixture the conductance, when calculated in the assumption that Λ_H (the conductance of hydrogen ion) is constant, was somewhat greater than the measured value; but the consistent nature of the deviations for all proportions of HCl and NaCl indicated that the ionization of HCl was determined by the total ion concentration and not by its absolute concentration. The transference experiments of Noyes and Sammet and Noyes and Kato show, however, that, if ACl remains constant, Λ_H increases rapidly with increasing concentration, and that the degree of ionization of HCl is almost the same as that of KCl. On using these results and assuming that the mobility of hydrogen ion depends only on the concentration of acid in the mixture, the calculated and measured values of conductances were found to agree very closely.

Heats of Combustion of Certain Liquid Hydrocarbons: T. W. Richards and R. H. Jesse, Jr.

In further prosecution of the revision of thermochemical data the heats of combustion of benzene and a number of octanes and xylenes were determined with unusual care. The object in choosing these substances was to endeavor to trace the effect of constitution or arrangement upon the heats of formation of isomeric substances and thus to obtain more definite idea of the relation of total energy-change to structure. The adiabatic method of calorimetry was used with great success, and in general the precautions used in previous work of this kind were adopted throughout, with several new improvements. Each specimen of volatile liquid was sealed in a flexible flattened glass bulb and ignited by means of a small weighed quantity of sugar placed above the bulbs on a glass shelf, the substances being contained in a very small narrow platinum crucible. When conducted in this way, the combustion was in every case complete. The final results showed very satisfactory agreement among themselves, and all will be soon published. This investigation will be continued in the near future, and the effort will be made to obtain as much light as possible upon the energy relations of these closely related compounds.

The Compressibilities of Certain Isomeric Hydrocarbons: T. W. Richards and C. L. Speyers.

In continuation of the work upon compressibility, described in Publications 7 and 26 of the Carnegie Institution of Washington, and in connection with the work above summarized concerning the heats of combustion of octanes and xylenes, the compressibilities of these substances at various temperatures was investigated in detail. The effort was made to attain greater accuracy than ever before. The standard of pressure was verified to a degree of precision far exceeding anything which had hitherto been attained. The new method for determining compressibility was found to give satisfaction as before. Five octanes were investigated with great care. Their compressibilities were found to vary over a much

wider limit than their heats of combustion, being comparable to the variations in the boiling point. In general, the isomers with higher boiling points possess lower compressibility, and the greater the density the less the compressibility; but there are interesting minor variations in these relationships which deserve further investigation. Ortho- and metaxylene and ethyl benzene also were investigated. The authors received important pecuniary assistance from the Carnegie Institution of Washington.

Electrochemical Investigation of Liquid Amalgams of Thallium, Indium, Tin, Zinc, Cadmium, Lead, Copper and Lithium: T. W. RICHARDS, J. H. WILSON and R. N. GARROD-THOMAS.

The investigation was a continuation of the research concerning amalgams of zinc and cadmium, described in a recent paper by Richards and Forbes. The object was to extend the study to elements possessing other valences and to study more accurately the phenomena investigated. The electromotive forces (and their temperature-coefficients) of various cells containing amalgams of the eight metals named in the title were measured with many precautions against experimental errors. Thallium and indium were found to behave in the same manner as cadmium, but in a much more exaggerated degree. Tin and lead were found to behave in the same manner as zinc, but likewise in a more exaggerated degree. It was shown that the greater part of these deviations from the concentration law may be explained by the heat of dilution of the amalgam, according to the equation of Cady. The temperature coefficient of a cell of this type was shown to correspond closely with the requirement of this equation. The difficulties of the actual measurement of thermochemical data involving amalgams were emphasized, and many errors in the work of previous investigators were discovered. It was shown that the deviations from the simple concentration law in every case decreased as the dilution increased, so that upon reaching a concentration of 0.01 gram-atom per liter all the amalgams investigated behaved practically as ideal solutions.

Further Investigation concerning the Atomic Weights of Silver, Lithium and Chlorine: THEODORE W. RICHARDS and HOBART HURD WILLARD.

This investigation consisted in a careful study of three ratios, namely, LiCl/AgCl, LiCl/Ag and $LiClO_4/LiCl$. By means of the latter two ratios the ratio of O_4/Ag was calculated, and new values were obtained in an entirely original way for the atomic weight of silver, lithium and chlorine. In the process of this work new methods of purifying lithium salts better than any preceding were devised. The lithium chloride was fused in such a way as to show perfect neutrality to the most sensitive indicators, and was weighed in a strictly anhydrous condition. The preparation of perchloric acid also was subjected to rigid scrutiny, and this substance was made in a state of unusual purity. A new precise method was devised for converting lithium chloride into lithium perchlorate, and its sources of error were carefully examined.

The atomic weight of lithium was found to be very nearly 6.94 (much less than Stas's value) and that of silver 107.871, if oxygen is taken as 16.000.

On the Velocities of Certain Reactions between Metals and Dissolved Halogens: RALPH G. VAN NAME and GRAHAM EDGAR.

Under like conditions the metals mercury, cadmium, zinc, copper and silver were found to dissolve in an aqueous iodine solution containing a large excess of potassium iodide at practically the same rate. In bromine mercury dissolves somewhat faster, in cupric bromide much slower than in iodine. The so-called diffusion theory of reaction velocity, of Noyes, Whitney and Nernst, seems to give a satisfactory explanation of the results obtained, as regards both the observed agreements and the change in the velocities with the conditions.

The Estimation of Radium Emanation and of Radium in Common Materials: MERLE RANDALL.

A definite quantity of radium emanation, obtained from a definite volume of a solution of the mineral uraninite, was introduced into electroscopes of the various types now in use for determining radium emanation. The values for the ionization current due to the emanation associated with one gram of uranium varied from 2.36×10^{-10} amperes for a Boltwood type to 4.80×10^{-10} for a Schmidt type. Thus it is incorrect to assume, as many European investigators have done, that data, expressed in amperes or C.G.S. units, obtained with one instrument, are directly comparable with those obtained with another. Some forms of apparatus for separating the emanation from solution removed a greater percentage than others. With all types the percentage loss was greater when the total amount of emanation present was small. Accurate de-

terminations can be obtained only when the methods and instruments are identical with those used in the standardization experiments, and the amount of emanation is also approximately the same.

On the Oxalates of Hydrazine: J. W. Turrentine.

Two oxalates of hydrazine have been prepared, the neutral monoxalate $(N_2H_4)_2.H_2C_2O_4$, and the acid dioxalate, $N_2H_4.H_2C_2O_4$. They crystallize from water in colorless plates.

The monoxalate is very soluble in water, while the dioxalate is only sparingly soluble in that solvent when cold. Both are insoluble in alcohol and ether. These salts do not exhibit definite melting points. When heated, intromolecular oxidation occurs with the formation—among other products—in the case of the monoxalate, of hydrazine hydrate, hydrocyanic acid or cyanogen, and a white crystalline sublimate which, from tests, appears to be a salt of hydrazine with an unidentified, carbonaceous acid, and in the case of the dioxalate, of ammonia, a cyanide and a white sublimate of an ammonium salt with some carbonaceous acid. A new method of analysis is described, especially applicable to the analysis of salts of hydrazine with easily oxidizable acids, whereby, with standard potassium permanganate solution, both the acid and the basic radicals of the oxalates are determined simultaneously.

Notes on the Preparation of Chromyl-Compounds: Harry Shipley Fry.

The paper is a résumé of attempts to prepare the unknown compounds chromyl bromide and chromyl iodide. While only partially successful in this respect, certain noteworthy results were obtained, namely: a new reaction for the preparation of chromyl chloride; a reaction for the detection of minute traces of chromyl chloride (0.00001 gm. per 1 c.c. of solvent) depending upon the formation and color of chromyl bromide; the preparation and identification of two new compounds—chromyl acetate and anhydrous chromic acetate.

The Solubility of Gold in Nitric Acid: Frederic P. Dewey.

Contrary to the general statement that gold is not soluble in any single acid, there are various statements in assay literature that gold may go into solution in the nitric acid during parting. After reviewing previous work upon the subject, the results of which are not, for various reasons, conclusive, this paper describes some tests upon the nitric acid after use for parting in gold bullion assays which gave most conclusive evidence that the acid did really carry gold.

These tests are followed by more elaborate ones upon larger amounts of gold and with increasing precautions. On two occasions 6 to 700 c.c. of solution were obtained, carrying more than 180 mg. of gold per liter.

A final crucial test, carried out with the utmost care, entirely in platinum, on about 30 grams of finely divided gold, by boiling it for two hours in previously boiled nitric acid of 1.42 sp. gr., yielded a solution which, after filtering, contained gold at the rate of over 660 mg. per liter.

It is shown to be very easy to dissolve finely divided gold in boiling nitric acid of 1.42 sp. gr.

On the Chief Determining Factor in the Toxicity of the Metal Ions: L. L. Woodruff and H. H. Bunzel.

Discussion of a series of experiments to determine the relative toxicity of various salts toward protoplasm. Results show a parallelism between the smallest fatal concentration of the various ions and their "ionic potential."

Metallic Titanium: Matthew A. Hunter.

The only successful preparation of pure titanium is that used by Nilson and Peterson by the reduction of $TiCl_4$ with sodium. Titanium so prepared does not differ in outward appearance from polished steel. It is however hard and brittle when cold. If however it be raised to a low red heat, it may be forged like red-hot iron. If the temperature be carried much above a low red the metal oxidizes superficially in air. Homogeneous rods 6 inches in length have been prepared and it is hoped to be able to prepare wire from them. The metal may be easily polished on an ordinary grindstone. It is too hard to be sawed by a hack saw but may be filed to shape by an ordinary file.

The specific gravity of the melted metal was found to be 4.51 at 18° C. The specific gravity of the forged material did not differ sensibly from this value. The melting point of the material is between 1,800 and 1,850° C. Analysis of the molten beads shows that the material is 100 per cent. titanium, containing no iron, sodium or oxygen as impurities.

Some New Double Arsenates: L. J. Curtman.

If to a hot ferric chloride solution, strongly acid with hydrochloric acid, diammonium arsenate solution be added to incipient precipitation, and the mixture heated, there forms a white finely divided precipitate which analysis showed to be

a double arsenate of ammonium and iron of the formula $NH_4H_2AsO_4.FeAsO_4$. Like the corresponding phosphate prepared by the author, the double arsenate readily hydrolyzes when washed with water. It readily dissolves in mineral acids, but is practically insoluble in 50 per cent. acetic acid. Ammonia dissolves it on heating to a deep reddish-brown solution from which 95 per cent. alcohol precipitates a basic double ammonium ferric arsenate. When sodium and potassium arsenates were respectively used under the same conditions, precipitates were obtained which from the results of qualitative analysis appear to be the double corresponding alkali arsenate.

Solubility Relations in Concentrated Solutions: ARTHUR E. HILL.

An effort has been made to calculate the solubility of a salt in solutions of a second electrolyte, throughout a wide range of concentrations. The lack of success of previous investigators has been due to the want of a dilution formula by which the dissociation of one salt might be accurately calculated in the presence of another, under which condition it has long been known that a change of degree of ionization occurs in addition to that brought out by chemical interaction. The formula most often used to express this "neutral salt effect" is that demanded by the isohydric principle of Arrhenius. It is known, however, that this formula always gives a calculated ionization greater than that experimentally found, and accordingly solubilities calculated by this method are always too low. Arrhenius himself, realizing the inadequateness of his formula, proposed one remedying the defect, but containing three constants. The author finds that an adequate formula may be written containing only the two constants of the Storch-Bancroft dilution formula for a single electrolyte, and proposes the expression

$$Cs = \frac{(Ca \times Ck)^n \left(\frac{\Sigma Ca \times \Sigma Ck}{Ca \times Ck}\right)^{\frac{n-1}{2}}}{K},$$

where Ca and Ck indicate the concentration of the anions and cathions respectively of the simple salt, ΣCa and ΣCk the total concentration of anions and cathions, and Cs the concentration of undissociated salt.

This dilution law has been used in calculating the solubility of several binary salts in presence of other electrolytes. In cases where the mixture contains no common ion, the calculated results agree with the experimental data within a few per cent. even in solutions of high concentration. In the case of mixtures containing a common ion the agreement is less nearly perfect, although in every case it is better than that obtained when the calculations are made according to the isohydric principle.

Measuring Capillary Ascension in Tubes of any Material: S. LAWRENCE BIGELOW.

An apparatus was shown with which the capillary ascension of any liquid in tubes of any material can be accurately and quickly determined.

Experimental results were given demonstrating that the ascension of water (and of benzene) was practically the same in tubes of glass, copper, silver and platinum.

The fact that water will ascend in tubes not wet by it, in tubes of paraffin, bees-wax and celluloid, was shown experimentally. The ascension in such tubes is about 70 per cent. of what it would be in glass tubes.

The ascensions of a saturated solution of sugar in a tube of sugar, and of a saturated solution of copper sulphate in a tube of copper sulphate, were measured and found to be about two thirds of the ascensions shown by the same solution in platinum tubes. Theoretical discussion of these results was deferred to the appearance of the article in the journals.

The Reaction between Bromic Acid and Hydriodic Acid in Concentrated Hydrochloric Acid Solution: D. L. RANDALL.

This paper compares the action of bromic acid and that of iodic acid on hydriodic acid in the presence of strong hydrochloric acid solution, and shows that while the reaction with iodic acid is

$$2KI + KIO_3 + 6HCl = 3KCl + 3H_2O + 3ICl$$

the reaction with bromic acid is

$$3KI + KBrO_3 + 6HCl = 4KCl + 3H_2O + IBr + 2ICl.$$

Test-tube Holder: H. EMERSON WETHERILL.

Results of three years' studies off and on on the most useful way to bend up a wire into a test-tube holder with a stand, cover glass holder feature, pinch cock, wide utility and practicability, clamp for various positions, opening by one hand.

The following papers are reported by title.

Some Observations on Phosphorescence: W. L. DUDLEY.

Solarization without Light: W. D. BANCROFT.

The Reduction of Zinc by Mercury and the E.M.F. of Zinc Amalgams: J. L. CRENSHAW.

Rôle of Water in Minerals: W. F. Hillebrand.
Ammonolysis of Hydrazine Sulphate: A. W. Browne and T. W. B. Welsh.
Quantitative Application of the Theory of Indicators to Volumetric Analysis: Arthur A. Noyes.
The Electrolysis of Copper Sulphate Solutions with Intermittent Current: W. Lash Miller.
A Revision of the Atomic Weight of Phosphorus: G. P. Baxter and Grinnell Jones.
A Revision of the Atomic Weight of Neodymium: G. P. Baxter and H. C. Chapin.
The Velocity of Saponification of Formic Esters: Julius Stieglitz.
The Influence of Acids and Alkalies upon the Activity of Invertase: C. S. Hudson and H. S. Paine.
Specific Heat and Heat of Neutralization of Aqueous Solutions: T. W. Richards and A. W. Rowe.
The Nature of Attractive Forces: J. E. Mills.
Changes in Volume during Solution of the Alkali Halides: G. P. Baxter.
A Simple Dynamic Method for Determining the Boiling-Points and Vapor Pressures of Liquids or Solids with Small Amounts of Material: Alexander Smith and Alan W. C. Menzies.
A Method for Determining Vapor Pressures: Alexander Smith and Alan W. C. Menzies.
A Redetermination of Vapor Pressures of Water and of Mercury: Alexander Smith and Alan W. C. Menzies.
A Quantitative Study of the Constitution of Calomel Vapor: Alexander Smith and Alan W. C. Menzies.
Wire Silver in Ores and how it is Formed: C. E. Swett.
The Electrical Deposition of Zinc: Elwood B. Spear.
The Determination of Antimony by the Gutzeit Method: Charles R. Sanger.
Molybdenum and Tungsten: Colin G. Fink.
Cæsium Nitrate and the Mass Action Law for Strong Electrolytes: E. W. Washburn and D. A. McInnes.
Cryoscopic-Cryohydric Studies: S. C. Lind.
The Influence of Temperature on the Formation of Water Gas: J. K. Clement and L. H. Adams.
A Method for Determining the Molecular Weights of Dissolved Substances by Measurement of Vapor Pressure: Alan W. C. Menzies.
The Condensation of Water by Electrolytes: F. K. Cameron and W. O. Robinson.
The Hydrolysis of Raffinose by Invertase: C. S. Hudson.
A Relation between the Chemical Constitution and the Optical Rotatory Power of the Sugar Lactones: C. S. Hudson.
A Constant Temperature Regulator: Edward Bartow and Frank Bachmann.
A New Method of Separating Chlorine, Bromine and Iodine: Louis Kahlenberg.
The Solubility Relations of Calcium Sulphate at High Temperatures: Arthur C. Melcher. (Presented by A. A. Noyes.)
A New Method of Determining the Potentials between Liquids: Gilbert N. Lewis.
Forces at the Boundary between Two Liquids: W. D. Harkins.
Chlorsulphonic Acid and Pyrosulphuryl Chloride: Charles R. Sanger.
The Electrical Conductivity of the Alcohols in Liquid Hydrogen Chloride: E. H. Archibald.

D. L. Randall,
Press Secretary

(To be continued)

The American Association for the Advancement of Science

Section K at the Boston Meeting

The sectional committee decided to hold one session, and to devote this to the discussion of a subject of general interest (especially to the entire field of physiology and experimental medicine), and to hold this meeting in conjunction with the American Physiological Society. The subject "Internal Secretion" was selected, and the following program was adopted;[1] all the papers were by invitation:

Tuesday, December 28, 1909, 2:30 P.M.

Joint meeting with the American Physiological Society, Lecture Room, Building B, Harvard Medical School.

Address of the retiring chairman: "Chemical Regulation in the Animal Body by Means of Activators, Kinases and Hormones," William H. Howell.

Symposium on Internal Secretion

"A General Review of the Chemical Aspect of Internal Secretion," by R. H. Chittenden.

"The Comparative Physiology of the Adrenal Bodies," by Swale Vincent.

[1] Professor Swale Vincent was unable to attend the meeting.

"The Internal Secretion of the Pancreas," by W. G. MacCallum.

"Our Present Knowledge of Thyroid Function," by S. P. Beebe.

"Metabolism after Parathyroidectomy," by J. V. Cooke.

"Physiological Consequences of Total and of Partial Hypophysectomy," by Harvey Cushing.

Executive Session (Section K).

The officers and committee members for the coming year will be:

Chairman—Frederick G. Novy.

Sectional Committee—Charles Sedgwick Minot, vice-president, 1909–10; George T. Kemp, secretary, 1909–13; Graham Lusk (one year); Jacques Loeb (two years); Elias P. Lyon (three years); William G. Gies (four years); William H. Howell (five years).

Member of the Council—Thomas G. Lee.

Member of General Committee—Clarence M. Jackson.

G. T. KEMP,
Secretary

SECTION F

AT the Boston meeting, Professor Jacob Reighard was elected vice-president for the next meeting; Professor F. I. Landacre, member of the council; Professor H. F. Nachtrieb, member of the sectional committee, and Professor E. L. Rice, member of the general committee.

Instead of the usual programs for the reading of technical zoological papers, a number of well-known zoologists cooperated in making general interest programs. The following lectures were delivered: Professor C. J. Herrick, "Evolution of Intelligence and its Organs"; Professor W. E. Ritter, "A Plea for Popular Zoology"; Professor Jacob Reighard, "The Nest-building Habits of some American Fishes" (illustrated); Dr. A. G. Mayer, "The Study of Natural History at the Tortugas Laboratory" (illustrated); Professor F. H. Herrick, "Illustrations of the Life and Instincts of Wild Birds" (illustrated); Dr. Daniel D. Jackson, "The House Fly as a Carrier of Disease" (illustrated by moving pictures furnished by Mr. Edward Hatch, Jr., of the Merchants' Association of New York, and exhibited by the Kleine Optical Co., of Boston); President David Starr Jordan, "Conservation of our Fisheries"; Professor W. E. Castle, "Recent Progress in Study of Heredity" (illustrated).

MAURICE A. BIGELOW,
Secretary

SOCIETIES AND ACADEMIES

THE TORREY BOTANICAL CLUB

THE meeting of December 14, 1909, was called to order at the American Museum of Natural History, with President Rusby in the chair.

The announced paper of the evening, on "The Reclamation of the Desert of the San Bernardino Valley," was then presented by Dr. Rusby and illustrated by some seventy lantern slides. The following abstract was prepared by the speaker.

The distinctions between desert and arid regions were explained and that under discussion was defined as being arid rather than desert, for the most part, although the production of cultivated crops without irrigation was impossible. The first settlement established was a Moravian mission near the present western boundary of Redlands. This was afterwards purchased by the Mormons, who instituted local irrigation. The first extensive irrigation operations were employed by the town of San Bernardino, the present water supply of which is about 1,200,000 gallons, obtained by the deflection of Lytle Creek, besides a large amount from deeply driven wells. This water supplies not only the requirements of the city, but those of a large cultivated area.

San Bernardino is near the western mouth of the large, somewhat horseshoe-shaped valley, from the mountains about which all the water of the valley must come, except that which falls during the rainy season, and which varies from six to twelve inches in the different parts of the valley, the larger amounts falling successively nearer the mountains. The moisture brought by the Pacific winds is precipitated in crossing these mountains during the winter season only. At the greater elevations, 10,000 to 12,000 feet, it is deposited as snow; lower, in the form of copious rains, and in the valley itself is a more or less scanty rainfall. During this period, moisture is not carried to the great interior plain of Nevada, Utah, Colorado, New Mexico and Arizona, where a dry season then prevails. In the summer, conditions are exactly reversed, no rain whatever falling west of the mountains. It thus happens that the San Bernardino valley gets its natural water supply at a time when cultivation can derive the least benefit from it and the problem is presented of preserving the winter supply and distributing it during the summer. The highly successful operations in the western part of the valley demonstrated the existence of a most fertile soil of great depth, and showed that the sole requirement for a rich agricultural region was an

abundant water supply. It was recognized that a town located at the eastern end, or top of the valley would be nearer the mountain supply and that its subterranean streams would be nearer the surface. The town of Redlands was therefore plotted, about twenty-two years ago, in an absolutely arid region. These calculations turned out to be perfect and the town of Redlands is now one of the most beautiful in the world, and surrounded by one of the most fertile of regions. Series of pictures illustrated the arid conditions which antedated irrigation, and were contrasted with others showing the rich orchards, vineyards and other cultivated tracts of the present day. Land previously absolutely worthless now yields rich dividends on a valuation of from one thousand to two thousand dollars per acre. Other pictures illustrated the snow-capped summits of winter, the humid, forest-clad slopes and the gradually changing flora of the descent to the plain. The Coniferæ of these mountains are of exceptional interest, because of their rarity or limited distribution. The very peculiar branch-system of *Pinus Sabiniana*, unlike that of any other pine, was well illustrated by several slides. It was remarked that the two fine characteristic specimens of this species exist in the Pinetum of the New York Botanical Garden. Other Coniferæ illustrated, besides many other forest species, were *Pinus Coulteri, Heyderia decurrens, Abies concolor* and *Pseudotsuga macrocarpa.*

The peculiar problems affecting the conduct of the water to the plains and its distribution to the consumer, arising from the tendency to loss through seepage and phenomenal evaporation, the legal questions arising in regard to water rights, the necessity of governmental regulation of water supplies, the methods of estimating the requirements of various crops, under different conditions, and the methods of measurement and sale of the water were discussed.

A large number of illustrations were presented showing the methods of applying water to the orchards and vineyards. Others illustrated typical fruit trees, in flower and fruit, fruit gathering, drying and packing. Many slides of very great beauty represented the street planting of trees and other methods employed to beautify the cities and their suburbs.

Percy Wilson,
Secretary

THE PHILOSOPHICAL SOCIETY OF WASHINGTON

The 674th meeting was held on January 15, 1910, Vice-president Rosa in the chair. The evening was devoted to hearing the address of the retiring president, Mr. C. K. Wead, on "Music and Science."

The speaker gave a brief sketch of the development of music, pointing out that rhythm is its most important feature; instrumental and vocal rhythm being entirely independent. Association, and combination of sounds for beauty of form, modulation and tonality were briefly explained. As regards expressiveness the musician does not attempt to put the music expression into thought.

Musical scale was defined, and the principles involved in the scales of various nations and periods were explained, among which Helmholtz's harmonic series was mentioned. No preeminent usage to fix a natural scale exists, our scale not following any law of a vibrating body. The four stages in the development of the musical scale were described. The phonograph is expected to be of importance in the study of native music.

The 675th meeting was neld on January 29, 1910, Vice-president Fischer presiding. Two papers were read.

The Sixteenth International Geodetic Conference:
Mr. O. H. Tittmann, of the Coast and Geodetic Survey.

The speaker gave a brief historical sketch of the origin and organization of the International Geodetic Association. The general conferences, according to present arrangements, take place triennially, the place for holding them is selected from several invitations officially extended by the delegates from various countries.

The sixteenth conference was held in London and Cambridge pursuant to an invitation by the British government, and its sessions began in London on September 21 and ended in Cambridge on September 29, the session being opened by addresses of welcome by Minister of War Haldane and by Sir George Darwin.

All but four of the twenty-two signatory powers were represented, and among those of the western hemisphere besides the United States and Great Britain were Mexico, Chili and Argentina. This is the first conference at which Canada was represented, and the speaker indulged the hope that the progress of geodesy in Canada will be such that its reports will hereafter furnish important contributions to the triennial conference.

The order of procedure of the conference was briefly outlined. The special reports refer to the

progress of triangulation, variation of latitude, deflections of the zenith, gravity observations and mean sea level determinations and leveling.

Some of the interesting topics discussed were mentioned, among which was the great progress made in the Cape to Cairo triangulation; base measurements with tapes, the use of which was so ably defended by the Americans as against the use of wire; the variation of latitude observations, especial attention being given to the method formulated by Dr. Ross and submitted by the speaker, for observing latitude photographically at Gaithersburg, Md. Dr. Hecker reported briefly on the gravity measures made in the Black Sea, with special reference to getting data and of testing the agreement between the theoretical effect of the velocity of the ship when going in an easterly or westerly direction on the observed intensity of gravity. Baron Eötvös gave an account of investigations with his torsion balance or gravity variometer, for determining the curvature of equipotential surfaces of the geoid.

One of the most important papers read at the conference was by Hayford on the reduction of gravity observations, the main feature of his method being that isostasy is taken into account, and the topographic correction is applied for the whole earth's surface. The methods and results contained in this paper elicited the following flattering comment from Dr. Helmert that "the Americans were to be congratulated on having introduced a new epoch in geodesy."

Many courtesies were extended to the delegates through Sir George Darwin acting as the representative of Great Britain and the University of Cambridge, and as a distinguished and hospitable citizen.

Some Apparent Variations of the Vertical Observed at the Cheltenham Magnetic Observatory: Mr. J. E. BURBANK, of the Coast and Geodetic Survey.

The paper discussed some changes of level of the piers on which the Omori seismograph has been mounted at the Cheltenham Magnetic Observatory. The instrument was first operated in the variation observatory where there is no diurnal range of temperature and the annual range is only about 2° to 3° C.

With falling external temperature, as in cold waves, the top of the W.-E. pier moved toward the east and the top of the N.-S. pier toward the south; with rising temperature there was reverse movement.

The W.-E. pier showed a distinct diurnal oscillation of level on all clear days. Shortly after sunrise it began to tip toward the east, reaching its maximum east deviation about 10 A.M., then it tipped toward the west reaching its maximum west deviation about 4 P.M., and then slowly returned to its normal position. This diurnal oscillation was superposed on the changes of level due to external temperature changes. This tilting of the pier began at an earlier hour in summer than in winter and the range varied greatly on different days, depending apparently on the intensity of the solar radiation. The range of motion was greatest in winter and had a yearly average of about one second of arc. The N.-S. pier did not show any appreciable diurnal variation of level.

These results are in good accord with similar observations made at Potsdam and Wilhelmshaven, Germany, both as regards the nature and magnitude of the diurnal oscillation of the level.

In October, 1907, the seismograph was moved to a new location on a massive concrete pier in a small house about one hundred yards southeast of its former location. When the external temperature rises this pier tips towards the southeast, oppositely to the pier in the variation house. There is a diurnal variation of level in the W.-E. direction but no appreciable change in the N.-S. direction.

This oscillation begins as a tilt towards the east about 10 to 11 A.M., and reaches a maximum east deviation about 4 to 5 P.M., and then returns slowly to the normal position; it appears only on clear days. The range is about the same as in the former location, but during clear winter weather when the nights are very cold the combined effect of the solar radiation and the external temperature changes may give an apparent oscillation as great as three seconds of arc. In mild summer weather when the temperature changes are small the oscillation rarely exceeds a half second of arc.

Sudden heavy downpours of rain cause this concrete pier to tip towards the northeast by an amount in some cases as great as three or four seconds of arc. When the ground is very dry before the rain, the pier receives a semi-permanent set and does not recover its former position for several days, if at all. When the ground is already partly saturated the pier recovers its former position more rapidly.

This tilting of the pier is undoubtedly local, as it did not appear on the records obtained in the variation house.

R. L. FARIS,
Secretary

THE CHEMICAL SOCIETY OF WASHINGTON

The 195th meeting was held at the George Washington University Lecture Hall on Thursday evening, January 13, 1910, President Failyer presiding. The attendance was forty-two. The report of the treasurer was read, showing a balance of $162 on hand. The secretary reported that during the past year the society had lost 71 members and had received 65 new members. The society granted a waiver of jurisdiction to the American Chemical Society over all of Virginia, except within a radius of twenty-five miles from Washington. Twenty-nine of the members lost to the society during the past year were within this jurisdiction. The total membership was reported as 240. Twenty-three papers were read during the year, fourteen of which were scientific and nine technical in character.

The following papers were read:

"Nitrification in Soils," by K. F. Kellerman, E. R. Allen and I. G. McBeth.

"Availability of Iodophenin in the Separation of Acetanilid and Acetphenetidin," by W. O. Emery.

"The Translocation of Plant Food during the Germination of Wheat," by J. F. Breazeale and J. A. LeClerc.

Dr. Kellerman showed that the modern viewpoint is that the soil must be considered alive, a matrix supporting various definite groups of microorganisms, and suggests the possibility that bacteriological diagnoses may determine the crop-producing power of different soils and the causes thereof. Although this work is yet in its infancy, during the last few years it has been shown that the action of the different groups, and especially the nitrifying bacteria in soil samples, correlates fairly well with the productiveness of the soils under field conditions.

Dr. Emery showed that it was possible to determine phenacetin in the presence of acetanilid.

In the last paper, Mr. Breazeale showed that during germination the little plantlet absorbed 96 per cent. of the nitrogen, potassium and phosphorus within the first ten days of germination, but that the potassium was absorbed at a much faster rate than were the nitrogen and phosphorus.

President Failyer appointed V. K. Chesnut chairman of the committee on communications, and C. L. Alsberg, chairman of the entertainment committee.

J. A. LeClerc,
Secretary

THE AMERICAN PHILOSOPHICAL SOCIETY

On the evening of January 21 President Nichols, of Dartmouth College, was to have addressed the American Philosophical Society, but in consequence of an attack of grip, was unable to be present. Dr. W. W. Keen, therefore, took his place, reading a paper on "Modern Antiseptic Surgery and the Rôle of Experiment in its Discovery and Development." He described the lamentable condition of surgery prior to Lister's epoch-making discoveries, then quoted chiefly from Lister the experiments both chemical, bacteriological, and finally those upon animals which gave Lister such a convincing proof of the value of his method that he then tried it upon man. Lister began with compound fractures, passing through abscesses, accidental wounds and finally making extensive purposeful wounds, *i. e.*, operations on the human body. This was followed by a statement of the condition of surgery at the present time, as contrasted with the pre-Listerian days.

The paper is one of the series being published by the Council on the Defense of Medical Research of the American Medical Association and will be published in full hereafter in the *Journal* of the American Medical Association.

On the evening of February 5 Professor Francis G. Benedict, of the Carnegie Nutrition Laboratory in Boston, read a paper on "The Influence of Mental and Muscular Work on Nutritive Processes." The paper described a series of metabolism experiments with a respiration calorimeter at Wesleyan University, Middletown, Conn. The influence of the sustained mental effort accompanying the taking of regular college mid-year examinations was studied. Twenty-two men spent three hours inside the chamber, during which time the water vaporized, carbon dioxide produced, oxygen consumed and heat produced were carefully measured. Compared with twenty-two control tests with the same individuals no changes in the gross metabolism attributable to mental effort were noted. A professional bicycle rider using a special form of bicycle ergometer inside the respiration chamber showed that mechanical efficiency of man was about 21 per cent. The resting energy output of 92 calories per hour was raised during severe exhausting work to over 600 calories per hour, of which 116 calories were transformed into effective work.

The Nutrition Laboratory of the Carnegie Institution of Washington in Boston is equipped with special apparatus for studying similar problems in metabolism.